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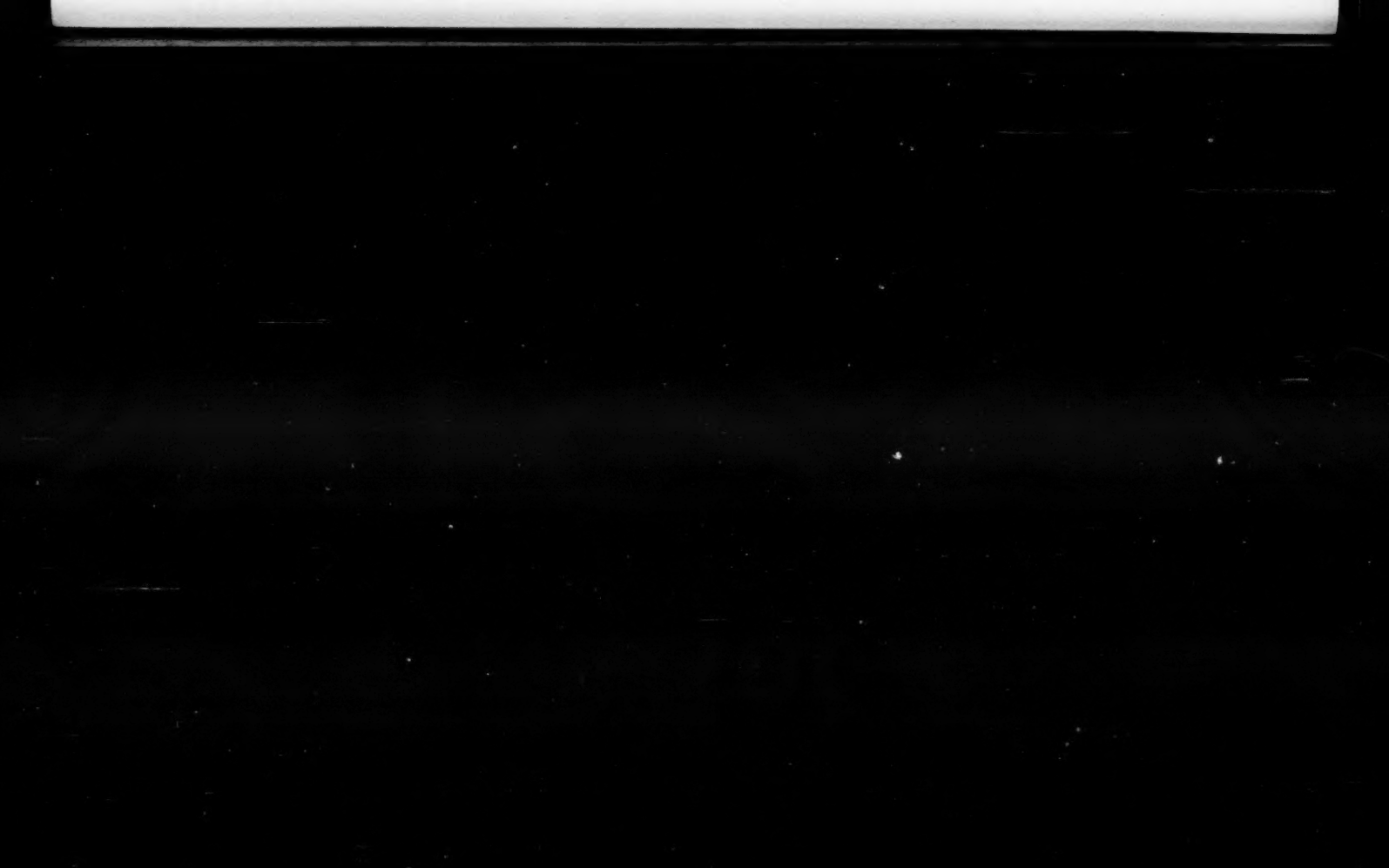

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SOME FEATURES OF GROWTH AND DEVELOPMENT OF HEREFORD CATTLE[1]

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University of California[3]

THE purpose of this paper is to present growth and development data, as represented by weights and body measurements, on pure-bred Hereford cattle maintained under favorable and reasonably uniform environmental conditions. Data on normal growth (in the sense that the animals were permitted to grow continuously to the limit of their inherent ability) are useful for a variety of purposes. They may be used for comparison with growth on different planes of nutrition, and with other herds, or breeds and in establishing production objectives for which nutrient allowances are to be calculated. Only the more obvious features of growth are presented. Kidwell, *et al.* (1951) reported on the application of allometry to some of these data.

Literature

In a series of papers (Lush, 1928, 1932 and Lush, Jones, Dameron and Carpenter, 1930) data were published on growth of beef cattle under range conditions, the changes in body measurements of steers during fattening, and the relation of body shape to rate of gain, dressing percent, and carcass value. Hammond (1920) made an extensive study on the relative growth and development of numerous breeds and crosses of cattle. These data were obtained from the Smithfield show records and are limited largely to animals about 22 and 33 months of age. Detailed carcass data were presented. Black, Knapp and Cook (1938) studied the correlation of the body measurements of slaughter steers with the rate and efficiency of gain and certain carcass characteristics. Measurements were made at time of slaughter and do not show changes with time. In a similar study Knapp (1939)

[1] This investigation became cooperative with the U.S.D.A., Bureau of Animal Industry and State Experiment Stations under Western Regional Project W-1 in 1948.

[2] The authors wish to acknowledge the assistance, over many years of the "Dean of Herdsmen", Alex McDonald in collection of the data. His native wisdom and Scot's instinct did not permit him to be optimistic that anything of great value in the improvement of beef cattle could be derived therefrom. Nevertheless, his ready cooperation and sound counsel have been extremely valuable. He even got so that he did not mind his fellow herdsmen catching him helping with such "monkey business"! Grateful acknowledgment is also made to W. C. Rollins for directing the statistical analyses and to Mrs. Patricia Chevalier, Cooperative Agent, Bureau of Animal Industry, U.S.D.A. who assembled much of the later data and carried out the statistical calculations.

[3] Division of Animal Husbandry, Davis, Calif.

reported upon the determination of slaughter-steer grades from weights and measurements. Except for the paper of Guilbert and McDonald (1933) we are not aware of any reports on growth of purebred cattle that extend from birth to maturity.

Material and Methods

Weight data have been collected at monthly intervals on the individual animals in the University purebred herd since 1925. Subjective evaluation by grading was inaugurated in 1935 and more complete performance records including a number of body measurements were begun in 1942.

Calves born in the autumn may sometimes receive grain during the winter, otherwise no grain is fed prior to weaning. Heifer calves weaned in the autumn are fed during the winter (about 3 months) 2 to 3 pounds of concentrates daily in addition to roughage *ad lib*. When pasture is available, no concentrates are fed to heifers after weaning. After weaning, bull calves are confined to lots and fed concentrates and hay to promote optimum gain and moderate fattening. During the last three years a number of bulls have been on individual feeding tests. They were fed a ration consisting of about 67 percent concentrates and 33 percent roughage according to appetite from 9 months of age until fattened to a degree comparable with low choice slaughter condition (presumably low prime according to 1951 designation). This represents a slightly higher plane of nutrition than formerly employed.

The present practice is to weigh all animals at monthly intervals until 24 months of age and yearly thereafter until 6 years of age. Weighing and measuring is done near the middle of each month. Calves are weighed and measured initially at the first regular "weigh day" following birth. They are then scheduled for measuring at the dates nearest 4, 8, 12, 16, 20, and 24 months of age. After 24 months all animals are measured and weighed once yearly in June.

Presentation of Data

Figure 1 gives the average growth curves for males and females including all the available data. Between the ages of 1 and 24 months, the curve represents the average for 70 to 107 females. For the older ages numbers averaged decline from 47 at three years to 28 at six years. Fifty-three to 75 individuals are included in the averages for bulls up to 16 months of age. Most of the bulls are removed from the

herd at about this age, so thereafter numbers are limited. Eighteen and eleven animals comprise the data at 20 and 24 months respectively. Thereafter, the general character of the growth curve is indicated by the dotted line based on the scattered and limited data.

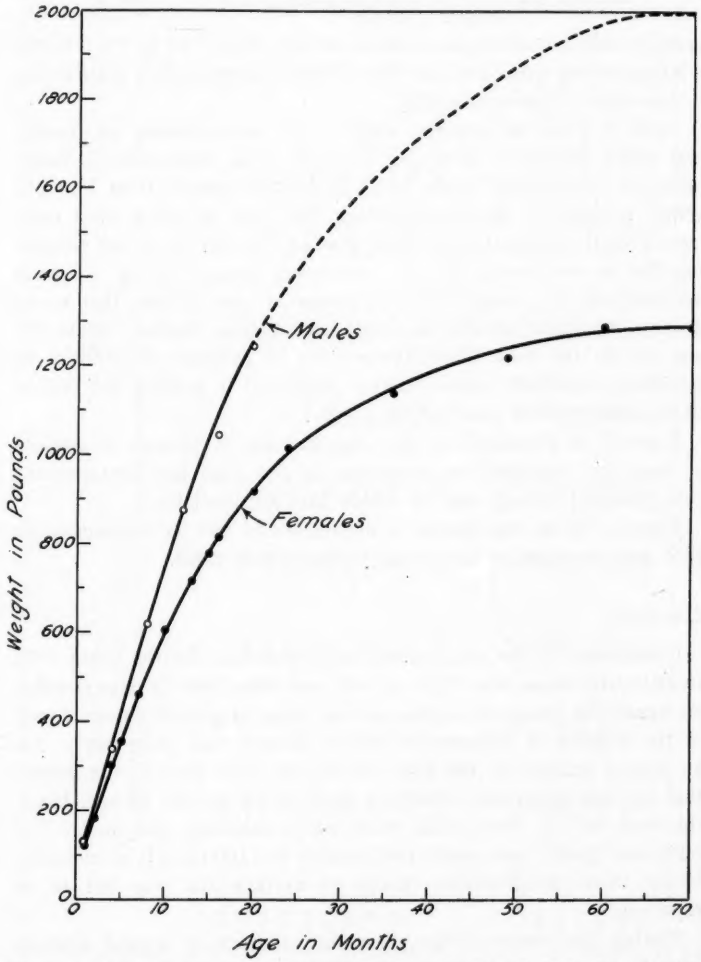

Figure 1. Average growth curves for purebred Hereford cattle, University of California herd.

Average weights and measurements for bulls and females are shown in Table 1. Included also is the index of conformation derived from dividing the round measurement by the height at withers (Gregory, 1933) and the reciprocal of the "dimension-weight" index of Yapp (1923), $\frac{\text{weight in pounds} \times 476 \text{ (av. cc. per lb.)}}{\text{height}^2 \times \text{length}}$ The average numerical grade of the animals represented is between 88–91 (2 to 2+) in the grading scheme (Guilbert and Hart, 1946) corresponding with choice to top choice commercial cattle.

Table 2 gives the average weights and measurements of females and males segregated according to grade. The segregation is based upon our "permanent" grade which is decided upon at from 1 to 2½ years—a range of age corresponding with that at which most commercial cattle are marketed. Those grading 2+ and above are grouped together, as are those grading 2— and lower. Animals in the "1" grade are relatively few, being "herd-bull prospects" and animals that would make a creditable showing in strong competition. Animals below 2— are rare in the herd. Thus, opportunity to evaluate possibilities of recording objectively characteristics considered in grading are limited to the rather narrow range of one grade.

Figure 2 is presented to show the increase of various dimensions at maturity, expressed as percentage of the 19th day measurement (the youngest average age for which data are available).

Figure 3 shows the change in dimensions of selected measurements with age, expressed as percentage of the mature value.

Discussion

Comparison of the average weight growth data for the years 1925 to 1933 with those from 1933 to 1940 and from 1940 to date revealed no significant change in mature size or shape of growth curves. Study of the weights of replacement heifers showed that only rarely was an animal retained in the herd, during the early part of the period, that did not weigh 650 pounds or more at 12 months of age. Later, this was one of the criteria upon which selection was made. The bulls used varied from about 1800 pounds to 2100 pounds at maturity. Under these circumstances change in average size was not to be expected.

During the course of the years the influence of several sires on growth rate and size were recorded. The average weight at 12 months of age of heifers from bulls used successively were as follows: Sire A,

TABLE 1. AVERAGE WEIGHT AND BODY MEASUREMENTS OF HEREFORD CATTLE

Number of Animals Averaged	Age	Weight[1]	Height[2] at Withers	Height at Hooks	Heart Girth	Length	Round	Width of Head	Length of Head	Width of Hooks	Width of Cannon	Round-Height Index	Dimension Weight Index
						Females							
52	19 days	113	68	72	81	69	57	12.7	24.1	17.3	2.8	82.6	16.4
48	122 "	300	85	91	113	96	75	16.1	32.3	27.7	3.6	88.0	20.2
54	244 "	499	97	102	138	113	87	18.3	37.2	34.6	4.2	89.9	22.4
56	364 "	657	103	109	153	124	94	19.7	40.3	38.7	4.4	90.6	23.5
57	483 "	824	109	114	167	133	98	20.9	42.4	43.8	4.8	90.6	25.1
53	608 "	912	112	117	173	139	102	21.6	43.8	46.7	5.0	91.3	24.9
52	732 "	1006	114	119	180	142	105	21.9	44.6	49.4	5.0	92.3	25.9
40	3 years	1142	118	122	187	149	108	22.4	46.2	53.4	5.2	91.3	26.2
32	4 "	1216	119	123	189	152	108	22.8	46.5	54.7	5.0	90.6	26.8
28	5 "	1283	120	124	193	156	110	22.9	46.6	55.8	5.0	91.9	27.3
25	6 "	1274	120	124	192	156	110	22.9	46.9	55.0	5.0	91.8	26.9
						Males							
50	19 days	118	69	73	82	71	59	12.9	25.5	17.5	3.0	84.8	16.4
49	124 "	336	87	93	116	100	79	17.1	33.8	28.0	3.8	90.6	20.8
44	248 "	605	100	106	145	120	94	19.8	39.6	35.6	4.5	93.8	23.9
42	369 "	872	109	114	167	134	106	21.9	43.9	40.8	5.2	97.0	25.8
36	487 "	1077	115	119	180	144	112	23.5	46.5	44.7	5.6	97.3	27.0
16	602 "	1237	118	122	190	150	116	24.7	48.6	49.2	6.0	98.1	27.8
7	752 "	1365	122	125	196	155	122	25.6	49.5	48.0	6.2	99.5	28.3

[1] Weights are in pounds.
[2] Measurements are in centimeters.

TABLE 2. AVERAGE WEIGHTS AND MEASUREMENTS OF FEMALES AND MALES SEGREGATED ACCORDING TO TYPE GRADE

Age	Grade	Weight[1]	Height[2] at Withers	Height at Hooks	Heart, Girth	Length	Round	Width of Head	Length of Head	Width of Hooks	Width of Cannon	Round / Height	Dimension Weight Index
Females													
8 mo.	2+	519	97	102	139	115	88	18.4	37.2	34.9	4.2	91.0	23.0
	2	490	97	103	138	112	86	18.4	37.3	34.3	4.1	89.4	22.4
	2—	468	97	102	136	110	84	18.1	36.8	34.0	4.0	87.9	21.3
12 mo.	2+	684	104	110	155	125	95	19.9	40.5	40.5	4.6	91.8	24.2
	2	653	103	109	152	125	94	19.7	40.5	39.2	4.6	91.2	22.9
	2—	596	102	108	149	121	89	19.2	39.9	38.7	4.2	87.1	22.6
16 mo.	2+	848	109	115	169	133	100	21.1	42.4	44.4	4.8	91.7	25.4
	2	794	108	114	164	132	97	20.8	42.7	43.1	4.8	89.4	24.9
	2—	794	108	113	163	133	95	20.4	42.0	42.9	4.8	88.6	24.1
8 mo.	2+	640	101	106	148	122	96	20.1	39.8	36.6	4.6	95.3	24.6
	2	606	101	107	145	119	95	19.7	39.8	35.2	4.5	94.0	24.0
	2—	551	99	104	141	117	90	19.4	38.7	34.8	4.4	91.4	22.9
12 mo.	2+	900	109	114	168	136	106	22.2	44.2	41.0	5.4	97.8	26.3
	2	873	109	115	168	134	106	21.9	44.1	40.6	5.2	96.6	25.8
	2—	813	108	113	163	132	104	21.7	43.0	40.6	4.9	96.3	25.0
16 mo.	2+	1133	115	120	183	146	113	23.8	47.0	45.5	5.8	98.5	28.0
	2	1072	115	120	180	145	111	23.5	46.8	44.6	5.8	96.7	26.6
	2—	966	113	117	172	139	109	22.9	45.3	43.5	5.2	96.0	25.8

[1] Weights are in pounds.
[2] Measurements are in centimeters.

633 pounds; Sire B, 730 pounds; Sire C, 684 pounds; Sire D, 673 pounds; Sire E, 597 pounds; Sire F, 683 pounds and Sire G, 666 pounds. Most of the variation can be attributed to the sire since there were many dams in common for calves from successive sires. Evidence of hereditary variation in growth pattern was observed but more detailed analyses will be required to reveal genetic significance.

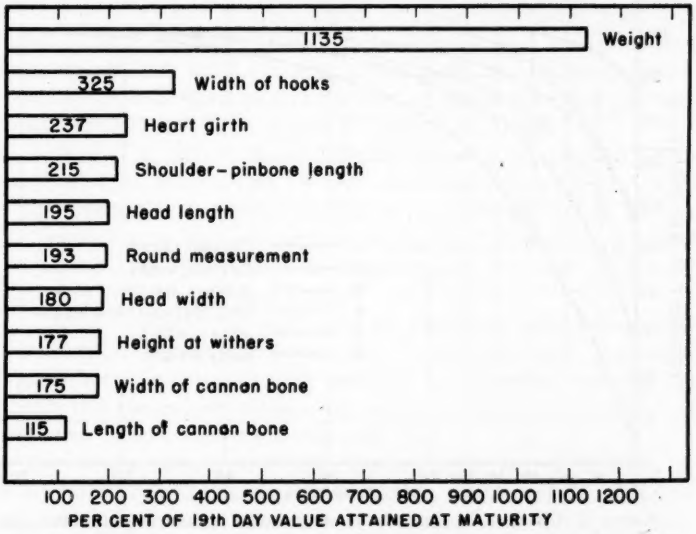

Figure 2. Mature value for various dimensions expressed as percentage of the 19th day measurement. Data on Hereford females.

It is well known that different parts of the body and different tissues grow at different rates and for varying periods of time; that a cow or bull is not just an enlarged calf. This differentiation is commonly designated as development, allometric or heterogenous growth. Some of the features of development revealed by the linear surface measurements are presented in Figures 2 and 3. These show that linear skeletal growth increases faster and matures earlier than thickness growth. Thus, width of hooks and weight are later maturing than height and length.

The cannon bone is among the earliest maturing parts. In calves, length of cannon is 85 to 90 per cent mature at birth while cannon bone width is about 55 percent of mature size. Shortness of leg has

long been associated with thickness of conformation and earliness of maturity. The relationship is fundamental but may, (and has been) carried to extreme with reduction in size, scale, soundness and general usefulness. As Hammond (1932, 1940) McMeekan (1943) and others have shown, shortening and thickening of bones is associated generally with shortening and thickening of muscles resulting in plump cuts of

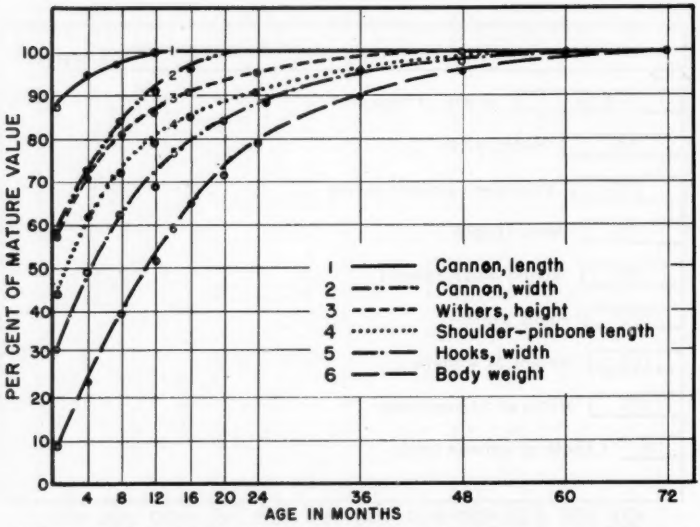

Figure 3. Changes in dimensions of selected measurements with age, expressed as percentage of the mature value. Data on Hereford females.

meat. Percentage meat to bone is not much altered in the process. Under the narrowly defined weight limitations of "Canterbury lamb," McMeekan (1943) was able to predict accurately the grade from the relation of thickness and length of cannon bone. Likewise, Callow (1945) demonstrated that carcass grade of mature cows could be predicted with reasonable accuracy from the relation of the weight of the feet and legs to the cold carcass weight. This was derived from a series of correlations and regressive equations relating weight of feet and legs as removed in slaughter to bone in the carcass; bone in the carcass to muscle tissue and fatty tissue; fatty tissue in the carcass to dressing percentage.

The data presented show that heifers attained approximately one-half of their mature weight at 12 months; bulls at 15 months. Under

uniform environmental conditions, weights at these ages are useful for size selection. According to the data, heifer weights were 97 percent that of bulls at 1 month; 89 percent at 4 months; 87 percent at 8 months; 77 percent at 12 months; and, about 65 percent at maturity.

Heads considered good in Hereford females had a ratio of length to width at the eye level of 2:1 or a little wider. Bulls tend to be somewhat wider and to increase more in width in relation to length during growth than females. Heads of these dimensions may lack other features commonly thought to be desirable such as muzzle size, contour, sex and breed character. Head width in relation to length is correlated with shortness and thickness of cannon bone and generally with thickness and large weight in relation to height.

Kidwell *et al.* (1951) reported heritability estimates for head length of about 0.96, whereas that for head width was practically zero. This would indicate that selection for head type is affected largely through change in length. Data accumulated during the "grading up" of cattle on the San Joaquin Experimental Range supports this view. (California Agr. Exp. Sta. Unpublished data.)

Extreme shortness of head may be associated with extremes in conformation—shortness of leg and compactness—and sometimes approaches achondroplasia with tendency for "overshot" jaw. On the theory that the shortest, thickest and widest are the best, these extremes are often given preference in the show ring.

One of the objectives of body measurements was to ascertain to what extent objective measurements could be substituted for subjective evaluation by grading. The data were segregated according to grade as outlined under "presentation of data." As mentioned, the opportunity to study objectively the characteristics considered in grading is confined to the rather narrow limits of one grade. Part of the data are given in Table 2.

Certain differences of comparatively small magnitude were consistent for all ages available including 4 months and older. There was no difference in height according to grade, but higher grading animals consistently were heavier and had larger round measurements. The trend with length was not so consistent, though there was some tendency for this and other measurements such as heart girth that are highly correlated with weight to be greater for the higher grades. A test of significance at 12 months of age was made. A covariance analysis which eliminated the effects of sex and age (around the age the measurements were taken) showed that there was no difference in height; that the differences in weight and round measurement were significant

at the 1 percent level. Grade 2+ exceeded grade 2 by 33.25 pounds; grade 2 exceeded grade 2— by 64.83 pounds. The corresponding differences in round measurement were 0.34 cm. and 4.0 cm. respectively. Thus, the magnitude of the differences were larger betwen grade 2 and 2— than between grade 2 and 2+ or over. This would suggest the probability of increasing divergences in the lower grades with conformation variations approaching the vanishing point in the higher grades. Since height was constant and the round measurement increase with grade was highly significant, it follows that the index, $\frac{\text{Round measurement} \times 100}{\text{Height}}$, was highly correlated with grade. Thus, it is evident that in conventional grading, preference is given to greater weight in relation to height and to greater general muscle thickness associated with plumpness of round.

These relations, however, offer no evidence that present ideals reflected by grading are correct; that progressively more weight or round in relation to height should be considered meritorious. Indeed, there is evidence that the contrary is true in many cases. Not infrequently animals grading in the low end of choice or upper end of good grade turn out to be the most profitable animals, both from the standpoint of production and carcass. It is possible that conformation now characterizing these intermediate grades may sometime represent the ideal and be designated grade 1. Similar changes in ideal type have occurred in swine.

Reference to Table 1 shows that the round-height index changes rapidly in the first few months, and tends to become constant in females at about 8 months; in males at about 12 months. Thus, this ratio is an indicator of earliness of maturity. Since the ratio changes with age and with fatness, it can only be used as an objective measure of type for animals that are comparable in age and plane of nutrition. Our limited observations indicate that if the ratio reaches 95 percent or more at 4 to 8 months the animal is destined to be small in size. This agrees with the general observation that exceptionally thick young calves attain mature shape and cease growing early and mature at small size. Those that have larger scale along with desired thickness in later life have more "stretch" at earlier ages.

The dimension-weight index reflects changes in conformation as the animal grows and develops and also distinguishes between animals varying in general thickness in relation to linear skeletal development. As with the round-height index, comparisons should be made between animals of comparable age and condition. The indices attained at

specified ages under uniform environment for animals found by other means to be ideal might be set up as a standard for selection and those that varied in *either* direction from the standard could be discriminated against.

Lush (1932) and others have shown that there is no generalizable correlation between conformation and rate or economy of gain. Kleiber (1933), Brody and Proctor (1932), Brody and Nesbit (1938), Kleiber and Mead (1941) and Guilbert and Gregory (1944) have shown that there is no fundamental relation between body size and efficiency of feed utilization. The recent experiments comparing small and conventional type Herefords confirm these findings (Stonaker and Wheeler, 1950, Willey *et al.*, 1951). The following generalization regarding size (Guilbert and Hart, 1946) appears justified and to have application to all species of meat animals: *"Ideal size can, in general, be defined as the largest that will under practical production conditions attain the desired carcass conformation and composition (proportion of lean, fat, and zone) at the weight and age demanded by the market."*

Although size as such and conformation are not fundamentally related to efficiency, "weight for age" has long been considered a criterion of desirability in meat animals. There is evidence that "weight for age" combined with judicious grading which estimates rate of maturity and development is a good practical index of efficiency. Between two animals having potentially *equal* mature size, the one that gains and matures more rapidly than the other under comparable environment is almost certain to be the more efficient. This derives from the proportion of feed used for maintenance and for production and involves the concept of relative gain and relative feed capacity (Kleiber, 1933). The conditions specified mean that one animal has in equal time produced more gain of higher energy value. In terms of growth, it is the shape of the growth curve rather than its magnitude that is related to efficiency, since the shape reflects rate of increase both in size and maturity. Judgment at early ages without advantage of the complete growth curve must rest upon observed rates of gain and the estimated maturity rate reflected by grade.

This concept doubtless has been the principal means of past improvement in efficiency and is the main basis of the performance-record scheme for purebred herds (Guilbert and Hart, 1946).

Energetic efficiency comparisons can be valid only when the energy content of the growth increments as well as that of the ration are equal. On the basis of individual feeding of bulls and heifers from about 500 to 800 pounds body weight Bogart and Blackwell (1950)

concluded bulls were more efficient than heifers. Since bulls and heifers of equal weight represent different segments of their respective growth curves, the composition of the gain is different and the conclusion unwarranted.

Conclusions

The ultimate criterion of choice in experimental procedures and statistical analyses is whether they will produce significant addition to biological knowledge. More practically, are the labor and expense involved justified by the resulting increase in biological knowledge? The question here is whether collection of measurement data are worthwhile. Production of meat animals deals with growth and development; therefore, it appears logical to attempt to measure growth in other ways besides weight. It is practically impossible to completely describe the appearance of an animal by linear surface measurements. Such measurements, furthermore, are not a means of determining the ideal or most useful animal. Once this has been derived from other information, measurements and relationships obtained therefrom may serve as an objective measure of deviations that occur and standards may be set up for selection purposes.

Measurements in addition to weight serve to describe more completely individuals or a population than can be done by weighing and grading. Over a period of years standards of subjective grading may change and leave no definite way to record whether or not the animals have been changed or in what direction and to what extent. If these linear measurements are recorded, at least some definite track has been left so that future investigators may follow it back and study the changes that may have been wrought through the breeding and selection procedures employed. Moreover, in cooperative investigations, comparison between herds, sire groups, or strains might be made more specific.

Regular measurements lead to knowing the animals better and are advantageous to the student of beef type, particularly if he also is teaching, judging, or is a professional judge. He will discover that frequently there are optical illusions involved in appraisal; the longer appearing may actually be shorter; that the "shallower bodied" animal may not be less deep but only standing on longer legs; that the "lighter in the round" may actually measure just as large but varied some in shape.

According to unpublished data (Calif. Agr. Exp. Sta.) variations in efficiency of feed use and ability to produce high carcass yield at

moderate fatness are major factors affecting profitability and liveweight value. Commonly, they are much more important than conformation variations as they affect cut-out value over the range from good to fancy feeder cattle. This also applies to differences in outward appearance as marked as that between choice Herefords and half-bred or "high-grade" Brahmans.

These factors are mentioned to bring into proper perspective measurements in relation to conformation. It appears that small differences in conformation have been over stressed and too little attention given to yield and efficiency.

The procedure from the research standpoint need not be too laborious or time consuming. The practice we employ represents about the maximum justifiable and involves a crew of four, one to two days per month to collect the data for a herd totalling about 130 head. On the San Joaquin Range, measurements were taken at weaning time each year of all animals in the herd up to 6 years of age. For the herd comprising about 270 animals, 4 days were usually required. This could be considered the minimum effort in data collecting that yields useful information.

Summary

Normal growth curves based on data collected over a period of twenty-five years from the University of California purebred Hereford herd are presented.

Body measurement data on males and females are summarized and discussed in relation to differential growth and development. Measurements and indices derived therefrom are considered in relation to subjection evaluation by grading. Some general problems in beef type selection are discussed.

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FEEDLOT AND CARCASS CHARACTERISTICS OF INDIVIDUALLY FED COMPREST AND CONVENTIONAL TYPE HEREFORD STEERS[1]

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"Then out of nowhere came 'Comprest' Herefords—and they really were a sight to behold. Although of popular bloodlines, the new type differed from anything thereto seen. Extremely lowset on ideal underpinning with smooth, bulging quarters and deep wide middles to match, with short thick necks and beautiful heads, the calves and yearlings were sensational."—Rank C. Forbes, Breeders' Gazette, October, 1946.

THE objectives of the present study on size and type in Hereford cattle were to compare the feedlot and carcass characteristics of conventional types with the comprest type in Herefords which has become prominent as winners in the major steer shows of the United States. The winnings of this type began in 1941 with the grand champion steer at the National Western Livestock Exposition, Denver, Colorado. Following this, either grand champion carloads or individual steer championships were won at Denver or the International Livestock Exposition, Chicago, from 1942 through to 1951. Since 1942, six grand champion carloads of steers at the International Livestock Exposition have been of a similar type.

Relationships between size and feed requirements have been studied previously in dairy and beef cattle, horses, sheep, and swine. Kleiber (1936) stated that total efficiency of energy utilization is essentially independent of body size. He pointed out that rabbits, sheep and cattle produce weight gains on almost identical food energy requirements. Proctor, *et al.* (1934) illustrated that efficiency of work production is similar in Shetland ponies and Percheron horses. Brody and Ragsdale (1935) stated that dairy goats, Jersey and Holstein cattle transfer food energy into milk energy with similar efficiency. Branaman (1940) in a comparison of the productivity of Southdown and Hampshire ewes and lambs found that the total digestible nutrients required for each 100 pounds of final feedlot weight of lamb produced

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were practically the same for Southdown and Hampshire single lambs. Zeller and Hetzer (1944) noted that small, intermediate and large types of Poland China barrows, when fed to a constant weight of 225 pounds, showed different feed requirements per 100 pounds of gain. The small type required approximately 20 pounds more feed per 100 pounds of gain. When pigs of the three types were fed to a constant degree of finish, feed requirements per 100 pounds of gain were similar. Woodward, Clark, and Cummings (1942) in a study of large and small types of Hereford cattle found that large type steers weighed more at birth and at weaning, gained faster and used somewhat less feed per 100 pounds of gain than small type Herefords. Both types were fed for a time constant period. Washburn *et al.* (1948) found in comparing nutrient utilization of three pairs of compact and conventional types of Shorthorn steers that conventional types gained 25 percent faster but feed costs per pound of gain were approximately equal for the two types. Conventional type steers required 70 more days on feed to be equivalent in finish to compact steers. Weber, Darlow, and Gerlaugh (1951) in studies of groups of large, intermediate and small types of steers, did not find significant differences in efficiency of gains and concluded that intermediate sizes best combine the gaining ability of large cattle with finishing ability of small cattle with about the same efficiency of gain. Willey *et al.* (1951) in comparing regular and comprest types, found that regular type cattle made significantly more rapid gains than comprest types. Differences in efficiency of gain, carcass characteristics and grades were not significant.

The outcome of efficiency of feed utilization experiments in time or weight constant feeding periods may be affected by differences in body size and composition. Knapp and Baker (1944) stated that correcting to a weight constant basis or feeding on a weight constant basis tends to eliminate the errors introduced under time constant feeding. Guilbert and Gregory (1944) also pointed out that comparing beef animals fed on a time-constant basis may introduce biased estimates of feed utilization where considerable variation in size and fatness exists and proposed feeding cattle to a constant degree of fatness in testing for efficiency of feed utilization.

Procedure

The 87 steer calves used in this experiment were the unselected progeny of comprest, intermediate and large types of purebred Here-

ford cows and 13 bulls of these three different types. The steers were calved in March, April, and May of 1947, 1948, and 1949, on the Ft. Lewis A. & M. College ranch near Durango, Colorado. They were weaned the latter part of November or the first of December and shipped to Ft. Collins, Colorado, where they were fed and slaughtered.

In the matings, 13 different bulls were used—five small or comprest, six intermediate, and two large size bulls. Only one bull was used in more than one season and this bull was used in only two seasons. Not until 1948 were any comprest females available. These comprest heifers were bred to comprest and intermediate type bulls. In classifying the entire calf crop, the comprest calves could readily be distinguished from the intermediate and large type calves. Only two steers were classified as large type. Because of this, intermediate and large types were included together in this study as representing conventional types of Hereford steers.

All male calves from the type experiment cows were castrated in June or July. The cows and calves were on range pasture typical of the area with no supplemental feeding before weaning. The stocking rate was approximately one cow and calf for each 20 to 30 acres of grazing land.

The fattening ration was a mixture of ground alfalfa, dry beet pulp, rolled barley, ground corn, and soybean oil meal. The starting mixture consisted of 60 percent alfalfa. The alfalfa was decreased and concentrates increased periodically until the mixture consisted of 25 percent alfalfa, 30 percent dry pulp, 15 percent barley, 15 percent corn, and 5 percent soybean oil meal. Individual self feeding was done by using wooden stanchions in which to lock the heads of the animals while their neck chains were snapped to manger chains. The animals were kept tied to their mangers from 5:00 p.m. until 8:00 a.m. During this time each steer had free access to the feed in his manger. Feed was weighed into individual storage barrels in approximately 100 pound lots. Enough fresh feed was given the steer each evening to provide some in excess of all he would eat by 8:00 a.m. The feed was weighed back fortnightly; weights and measurements of the steers were taken every 28 days.

The goal was to feed each steer until he reached a finish of low choice or had developed approximately ½ inch of fat over the ribs. The meats specialist selected each week for slaughter those animals which he judged were sufficiently fat.

Photographs and weights were taken of each steer slaughtered. Appraisals of each live animal and its carcass were made, using the

beef scoring charts developed by the U.S.D.A. Bureau of Animal Industry. Carcass weights were taken and detailed carcass cut out tests were made, again using procedures as outlined by Hankins and Howe (1946). Photographs of round and rib cross sections were made as well as tracings of the cross section of the rib cut.

Analyses of the variance of type, year and interaction effects were made by the use of RX2 tables with disproportionate subclass numbers as outlined by Snedecor (1950).

Results

Of the measurements taken there was within any one year practically no over lap in the wither heights nor in lengths of cannon bones in the live steers of the two types previous to slaughter. The differences between the two types were highly significant (table 1). Year differences were also highly significant and the cause was not clear. The comprest type steers averaged nine days younger than the conventional type steers although the bulls were turned into the pastures with the cows on the same dates. Slaughter ages were slightly less for the comprest type steers and they required about a week less time on feed. This difference was not significant. The ages of the dams differed somewhat, although the cows were allotted equally by ages among the sires. In the 1950 calf crop, comprest type calves were mostly from two and three year old dams. The weaning weights of the steer calves differed significantly although the amount varied considerably from year to year. The comprest type steers were consistently given higher feeder grades than were the conventional type calves. Differences in slaughter weights and daily gains were large and highly significant. The comprest type steers reached the low choice grade at an average weight of 689 pounds, whereas conventional type steers averaged 852 pounds when ready for slaughter. Although the comprest type steers gained approximately 20 percent less per day, they ate about 20 percent less feed per day and thus required almost exactly the same total digestible nutrients to produce a pound of gain as did the larger steers. Fat steer grades, as determined by visual and manual appraisal of condition or fatness, were almost the same for the two types; although there was a 20 percent difference in the grades for the "compactness" of animals in the two groups.

The carcasses from the conventional type steers were about 100 pounds heavier than those from the comprest steers. This difference was highly significant. Each right side was separated into the major

TABLE 1. MEANS OF FEEDLOT AND CARCASS CHARACTERISTICS OF COMPREST AND CONVENTIONAL TYPES OF HEREFORD STEERS

No. of Steers	Comprest Type 5	13	6	Un-weighted Means	Conventional Type 22	17	24	Un-weighted Means	Levels of Significance		
Characteristic:	1948	1949	1950		1948	1949	1950		Type	Year	TxY
Cannon bone length (cm.)	18.9	15.8	16.6	17.1	22.2	18.2	19.2	19.9	**	**	ns
Wither height (cm.)	100.6	100.0	100.5	100.4	112.6	106.6	112.2	110.5			
Initial age (days)	240	225	223	229	247	229	237	238			
Slaughter age (days)	430	419	430	426	440	446	444	443			
Days on feed	190	194	207	197	193	217	207	205	ns	*	*
Dam's ages (years)	4.2	6.7	2.7	4.5	4.1	5.0	6.9	5.3			
Initial wt. (lbs.)	355	359	299	338	448	374	414	412	**	ns	**
Slaughter wt. (lbs.)	683	695	688	689	858	836	863	852	**	ns	ns
Feedlot gain (lbs.)	328	336	389	351	409	462	442	438			
Daily gain (lbs.)	1.72	1.76	1.89	1.79	2.12	2.14	2.15	2.14	**	ns	ns
Dig. Nutrients/100 lbs. gain	500	497	430	476	506	464	466	479	ns	**	**
Feeder grade †	4.7	5.6	5.1	5.1	4.2	4.2	4.7	4.4			
Fat steer grade †	4.5	4.4	4.4	4.4	4.3	4.3	4.4	4.3	ns	ns	ns
Fat steer compactness †	5.3	5.1	5.1	5.2	4.4	4.3	4.2	4.3			
Carcass grade †	4.5	4.4	4.6	4.5	4.3	4.5	4.4	4.4	*	ns	ns
Carcass compactness †	5.6	5.2	4.8	5.2	4.3	4.1	4.1	4.2			
Carcass weight (right side)	193	204	193	197	252	248	248	249	**	ns	ns

TABLE 1. MEANS OF FEEDLOT AND CARCASS CHARACTERISTICS OF COMPREST AND CONVENTIONAL TYPES OF HEREFORD STEERS—*Continued*

No. of Steers	Comprest Type 5	13	6	Un-weighted Means	Conventional Type 22	17	24	Un-weighted Means	Levels of Significance		
Characteristic:	1948	1949	1950		1948	1949	1950		Type	Year	TxY
Percentage rib	9.0	9.3	9.2	9.2	9.5	9.4	9.4	9.4	*	ns	ns
" chuck	23.1	23.5	23.4	23.3	24.0	24.3	24.7	24.3	**	**	ns
" navel end	7.6	7.3	7.2	7.4	7.3	7.2	6.9	7.1			
" brisket	6.1	5.8	5.5	5.8	5.4	5.4	5.3	5.4			
" shank	4.9	4.6	4.6	4.7	4.8	4.4	4.5	4.6			
" loin	17.7	16.4	16.4	16.8	16.6	16.6	16.2	16.5	ns	ns	ns
" round	24.1	25.0	25.0	24.7	24.8	24.7	24.8	24.8	ns	ns	ns
" flank	4.9	5.6	5.5	5.3	4.4	5.3	5.1	4.9			
" kidney knob	2.6	2.6	2.9	2.7	2.6	2.7	3.1	2.8			
Area of rib eye ($cm.^2$)	47.7	52.5	47.8	49.3	58.5	54.7	56.4	56.5	**	ns	*
Rib fat thickness (cm.)	1.26	1.22	1.34	1.27	1.17	1.17	1.29	1.21	ns	ns	ns
Dressing percentage	57.1	59.4	56.5	57.7	59.3	59.7	57.8	58.9	**	**	ns
Composition of 9–10–11 rib:											
Percentage bone	16.3	15.1	15.3	15.6	16.8	14.7	14.8	15.4	ns	**	ns
Percentage lean	51.1	52.5	52.4	52.0	53.9	50.6	52.4	52.3	ns	ns	ns
Percentage fat	32.6	30.7	30.4	31.2	29.3	32.9	31.2	31.1	ns	ns	*
Percentage other	....	1.8	2.0	1.3	....	1.9	1.5	1.1			

† Grading system: 6=fancy or prime, 5=choice, 4=good.
**=.01 level, *=.05 level, ns=non-significant.
Level of significance not studied for all traits.

wholesale cuts. These cuts from the comprest type carcasses were consistently lighter than the cuts from the conventional type carcasses. However, each cut's weight as a percentage of the weight of the entire side was not greatly different for both types of cattle. Tests of significance were made on four major cuts—ribs, chucks, loins, and rounds. Between type differences of .2 and 1.0 percent in ribs and chucks were statistically significant, probably as a result of the consistent relationship between the means of the types during the three years. The area of the cross-section of the rib eye was significantly less for the comprest type cattle; but the thickness of fat over the eleventh rib was approximately equal for the two types. Carcass composition as estimated from the physical separation of the bone, fat, and lean from the 9–10–11 rib cut indicated almost identical composition. Dressing percentages of the conventional type steers were approximately 1 percent greater than for the comprest. This difference, though small, was consistent over the three years of the study and was highly significant.

Discussion

This study has demonstrated that some of the major size differences within the Hereford breed of cattle were not associated with economy of gain of steer calves. Rates of gain, total gain and total feed consumption were greatly different and appeared to be a function of size. In the experiment, the objective was to feed the steers to a constant degree of fatness. Although the method for determining this end point was subjective, the composition of the rib cuts showed that almost identical percentages of bone, lean and fat were obtained from the two size or type groups. Thus while a fat constant criteria has not adapted itself to objective means of measurement, it appeared, in testing animals which may vary considerably in size, to be useful in eliminating results in which efficiency is confounded with body composition effects. Such conditions may exist in experiments where feeding is done for similar periods of time or between constant beginning and end weights.

While the shapes and sizes of the live steers and their carcasses were strikingly different (the comprest steers appearing more compact) the percentages of the major cuts from the carcasses were almost identical. With comprest cattle, the weight of cuts from yearling beef carcasses were 20 percent lighter without a reduction in percentage fatness.

No measurable evaluation of consumer preference so far as differences in sizes of cuts produced from these steers in this study has been made. At this time, and in light of the findings from this study, it appears that the effect of size on such unknowns as price differential at the consumer level, reproductive performance and breeding herd costs should determine future size trends.

Summary

Comprest type steer calves, when individually fed to a low choice slaughter grade, gained as efficiently per unit of feed eaten as did conventional type steer calves. The conventional type steers ate more, gained more per day, and reached the slaughter grade of low choice weighing about 20 percent more than the comprest steers. Differences in rate of gain and slaughter weights were highly significant. Differences in efficiency of gain, days on feed and slaughter ages were not significant.

Dressing percentages were consistently and significantly different. Conventional type steers dressed 1 percent higher. Comprest type steer carcasses were graded the same on finish but about 20 percent higher on compactness. There were highly significant differences in carcass weights. Comprest type carcasses averaged 394 pounds; conventional type carcasses averaged 498 pounds. Physical separation of the 9–10–11 rib cuts into bone, lean and fat showed almost identical composition for the two types. The percentages of the major cuts in the carcasses of the two types were similar.

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WINTER HAY CONSUMPTION OF BREEDING FEMALES OF LARGE, INTERMEDIATE, AND COMPREST TYPES HEREFORD CATTLE[1]

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THE effect of size of beef cattle on the beef output from a given land area must of necessity include a study of the effect of body size in breeding cows and heifers on consumption of forage. This study consisted of three years of comparisons of winter hay consumption of Hereford breeding females of comprest, intermediate and large sizes of three ages—calves, bred yearlings and bred two-year-olds.

The gains of calves, heifers and cows of large and small types have been reported by Woodward, Clark, and Cummings (1942). The winter and summer gains of larger type cattle were generally greater. Hay consumption according to the different sizes was not reported.

Other experiments with steers were reviewed by Stonaker, Hazaleus, and Wheeler (1951). In general they illustrate that while rate of gain is directly associated with mature body size, efficiency of gains to a constant degree of fatness are relatively independent of body size. Guilbert and Loosli (1951) have recently surveyed this general phenomenon for different species.

Procedure

The cattle were fed at Ft. Lewis A & M College during the winters of 1949, 1950, and 1951. Large, intermediate and comprest type females of two different ages were fed each winter, thus providing a 3×2 factorial design in each of the three years. In all, 18 lots of cattle were fed—six lots of each type and six lots of each age group. These lots and the number of animals per lot were distributed through the three years as shown in table 1.

The beginning of the feeding period was determined largely by the date on which snowfall became sufficiently heavy to begin regular hay

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feeding. The feeding trials were terminated in March and April since calving began about the latter part of March.

The females were sorted into lots on the basis of age and size. Skeletal size as measured by wither height was used since it was found to be a discriminating and useable measurement for differentiating comprest from other sizes (Stonaker, Hazaleus, Wheeler, 1951). The yearlings and two-year-olds had been exposed to bulls during July and August of the previous year. In the lots of bred two-year-olds there were similar percentages of animals which had nursed calves the previous year.

In all years, an alfalfa and grass hay was fed. The calves and bred yearlings were fed *ad lib*. The bred two-year-olds were limited-fed so

TABLE 1. THE AGES, SIZES, TYPES, AND NUMBERS OF FEMALES USED IN WINTER HAY CONSUMPTION EXPERIMENTS

	Calves Age 8 months			Bred Yearlings Age 20 months			Bred Twos Age 32 months		
	Large	Inter.	Comp.	Large	Inter.	Comp.	Large	Inter.	Comp.
No. in 1949	15	15	10	15	15	15	—	—	—
Days on feed	112	112	112	56	56	56	—	—	—
No. in 1950	—	—	—	12	12	10	10	10	10
Days on feed	—	—	—	84	84	84	70	70	70
No. in 1951	15	15	9	—	—	—	12	12	10
Days on feed	84	84	84	—	—	—	84	84	84

that they gained about 8 percent of their body weight. The objective was to have them strong but wintered as economically as feasible.

The cattle were fed once daily. They had salt and running water available at all times. The first year they were sheltered against prevailing north and west winds by a board fence. During the second and third years a shed shelter was available. At Ft. Lewis the altitude is approximately 7600 feet above sea level. Snow fall in the area is heavy and the January temperature averages 22° F.

As may be noted from table 1, age and year effects were confounded because the same age cattle were not available for feeding in each of the three years. Also the number of animals per lot varied but since it was between nine and 15, the reliabilities of the means would not be expected to differ greatly. The major item of comparison (that between types) was orthogonal. Within any one year, age differences also could be compared.

Results

The results classified themselves into observations of two different kinds: first, those characteristics which define size or may be a function of size such as wither height, body weight, feed consumption per day, and daily gain, and, second, those observations which are made up of ratios which describe performance relative to the size of the animal such as feed consumption per unit of body weight and feed consumption per unit of gain.

Differences between types for the characteristics in the first category were highly significant as shown in table 3.

The means of the same observations noted in table 2 are presented in

TABLE 2. SIGNIFICANCE OF TYPE DIFFERENCES FOR CHARACTERISTICS DESCRIBING OR ASSOCIATED WITH SIZE IN HEREFORD FEMALES

Variability due to	D/F	Mean Squares			
		Initial wither heights	Average weight	Feed per day	Daily gain
Totals	17				
Types	2	46.05**	49,359.72**	15.24**	.075*
Age—Year	5	45.18**	134,460.89**	23.75**	.137**
Type x Age—Year	10	.72	1,318.39	1.45	.012

* Significance at .05.
** Significance at .01.

table 3 by age and year classification. It is possible in this table to compare different ages for any one year. Thus in 1949 one may compare calves with bred yearlings. In 1950, yearlings may be compared with bred twos, and in 1951 calves may be compared with bred twos. Likewise some comparisons of year effects may be made by pairing 1949 vs 1951 for calves, 1949 vs 1950 for bred yearlings, and 1950 vs 1951 for bred twos. Type X year interactions may have been appreciable, for the relationship between the means of different types varied from year to year. The significance of differences between any two age-year group means may be obtained by comparing the difference between the means with the values of least significant differences (L.S.D.) in table 3. Differences in age groups were significant except for daily gain when full-fed yearling heifers were compared with limited-fed two-year-olds.

For those characteristics consisting of size constant ratios, differences between types were not significant as shown in table 4.

The means for these size constant ratios are presented in table 5.

TABLE 3. MEANS OF CHARACTERISTICS DESCRIBING OR ASSOCIATED WITH SIZE IN HEREFORD FEMALES

	Calves			Bred Yearlings			Bred Twos[1]		
Initial Wither Heights (Inches). L.S.D. for age-year groups @ .05=1.5; @ .01=2.2									
	Large	Inter.	Comp.	Large	Inter.	Comp.	Large	Inter.	Comp.
1949	38.3	37.3	35.1	46.1	43.9	39.3	—	—	—
1950	—	—	—	44.8	42.3	40.0	47.1	44.8	40.4
1951	39.1	34.9	33.1	—	—	—	47.7	44.8	42.0
Average Weights (Pounds) L.S.D. for age-year groups @ .05=66; @ .01=94									
	Large	Inter.	Comp.	Large	Inter.	Comp.	Large	Inter.	Comp.
1949	489	429	390	861	734	690	—	—	—
1950	—	—	—	872	736	681	1040	913	774
1951	510	375	386	—	—	—	972	872	748
Hay Per Day (Pounds). L.S.D. for age-year groups @ .05=2.2; @ .01=3.1									
	Large	Inter.	Comp.	Large	Inter.	Comp.	Large	Inter.	Comp.
1949	11.9	11.2	10.6	19.0	19.0	16.0	—	—	—
1950	—	—	—	16.3	15.4	13.7	20.2	17.4	14.7
1951	12.9	10.4	11.8	—	—	—	17.3	15.5	11.7
Daily Gain (Pounds). L.S.D. for age-year groups @ .05=.20; @ .01=.29									
	Large	Inter.	Comp.	Large	Inter.	Comp.	Large	Inter.	Comp.
1949	1.21	.98	.91	1.53	1.55	1.62	—	—	—
1950	—	—	—	1.24	1.17	.95	1.04	1.20	.90
1951	1.11	.97	.86	—	—	—	1.39	1.12	.95

[1] Limited-fed, other ages fed *ad lib.*

In the ratio hay per day per 1000 pounds of animal, average weight was based upon the average of the individual weights taken every 28 days during the feeding period.

The means in table 5 indicated a general lack of association between size within an age group and the amount of hay required to winter 1000 pounds of breeding animal. The inconsistencies were particularly apparent for the bred yearlings and twos. There was some indication that 1000 pounds of large type calves would eat less hay per day than 1000 pounds of either intermediate or comprest type calves and gain

slightly more efficiently. However, these differences were not statistically significant.

Calves ate significantly more hay per 1000 pounds of body weight than did either full-fed, bred yearlings or limited-fed bred two-year-

TABLE 4. SIGNIFICANCE OF TYPE DIFFERENCES IN SIZE CONSTANT RATIOS IN HEREFORD FEMALES

Variability Due to	D/F	Mean Squares	
		Hay Per Day Per 1000 lbs. Weight of Animal	Hay Eaten per Unit of Gain
Total	17		
Types	2	5.7	.46
Age-Year	5	51.9**	13.23*
Types x Age—Year	10	2.5	2.37

* $P \leq 0.05$. ** $P \leq 0.01$.

TABLE 5. MEANS OF SIZE CONSTANT RATIOS IN HEREFORD FEMALES BY TYPES, AGES, AND YEARS

	Calves			Bred Yearlings			Bred Twos[1]		
Pounds of hay consumed per day per 1000 pounds of body weight. L.S.D. for age-year groups @ .05=2.8 lbs.; @ .01=4.0 lbs.									
	Large	Inter.	Comp.	Large	Inter.	Comp.	Large	Inter.	Comp.
1949	24	26	27	22	26	23	—	—	—
1950	—	—	—	19	21	20	19	19	19
1951	25	28	31	—	—	—	18	18	16
Pounds of hay consumed per pound of gain. L.S.D. for age-year groups @ .05=2.8 lbs.; @ .01=4.0									
	Large	Inter.	Comp.	Large	Inter.	Comp.	Large	Inter.	Comp.
1949	9.8	11.4	11.6	12.4	12.2	9.8	—	—	—
1950	—	—	—	13.2	13.1	14.5	19.2	14.5	16.5
1951	11.6	10.6	13.6	—	—	—	12.5	13.8	12.2

[1] Limited-fed, other ages fed *ad lib.*

olds. Full-fed yearlings ate about the same per 1000 pounds of body weight as limited-fed two-year-olds. In 1950 the bred two-year-olds ate significantly less per pound of gain than did bred yearlings. Other differences between age groups in efficiency of gains were not significant.

Discussion

The three different age groups of Hereford females fed in the winters of 1949, 1950 and 1951 were wintered much as ranchers would winter cattle of these age groups. The heifer calves and the bred yearlings were allowed to eat all the hay they would consume. The bred two-year-olds (these cows would be three the following spring) were fed limited amounts of hay so as to gain a sufficient amount of weight to permit development of the fetus without an appreciable reduction of skeletal and muscular development. Comparisons concerning the winter maintenance requirements of calves with yearlings were subject to the qualification that the yearlings had been exposed to bulls and most of them were in calf. Thus while comparisons between age groups of cattle would be subject to these limitations, the comparisons between size groups within an age group were not confounded with other variables.

There were general similarities in the behavior of different sizes of heifers in this experiment and the fattening phase of the experiment previously reported. The observations in this study classified themselves into two rather distinct kinds. The first consisted of those associated directly with over-all body size, such as wither height, average weight, feed eaten per day, and daily gain. For all of these characteristics highly significant differences in size groups have been found just as was the case with the steer feeding experiment. The second was the study of ratios of characteristics such as feed eaten per unit of body weight or feed consumed per unit of gain. There appeared to be no consistent association between these ratios and body size differences.

As a result of these observations it would appear that so far as a given land area is concerned, about the same tonnage of similar aged breeding cattle could be maintained and this may be independent of their individual size characteristics. This includes a major assumption that the grass consumption of heifer calves and yearlings is proportionately the same as the pounds of hay eaten when they are full-fed in the dry lot. In the light of the winter hay consumption experiment and of the fattening experiment of steers of different sizes, it appeared that cattle of the same age consumed feed in direct proportion to their body weight.

On an operational basis, the performance of cattle of different ages is of some interest. As might have been expected the average hay consumption per day was considerably greater for yearlings than for calves. However, full-fed yearlings ate somewhat less than limited-fed two-year-olds when those two-year-olds were fed so as to winter in only

strong condition. Calves consumed more hay per ton of body weight than yearling or two-year old heifers. On the other hand, the full-fed bred yearlings ate about the same per ton of body weight as did the limited-fed, bred two-year-olds. There appeared to be a slight tendency for the calves to require a little less hay to make a pound of gain than for the bred twos or the bred yearlings. However, these differences were not significant. It would seem reasonable that there might have been a greater difference in the efficiency of gain had the yearlings not been bred.

Summary

Six lots of Hereford females of two ages and three sizes—large, intermediate and comprest were wintered on hay in each of three years—1949, 1950, and 1951. The primary object of the experiment was to check the daily gains and hay consumption of these different sizes of females relative to their body weight. In 1949 three lots of large, intermediate and comprest type heifer calves and three lots of large, intermediate and small type bred yearlings were full-fed hay. In the winter of 1950 three lots of bred yearlings, full-fed, and three lots of bred two-year-olds, limited-fed, were compared and in 1951 three lots of calves, full-fed, were compared with three lots of two-year-olds, limited-fed. The classification according to type was based upon an estimation of skeletal size as measured by wither heights. The wither height measurements were highly significantly different for the different sizes within an age group. Likewise there were highly significant differences between the types for the average weight maintained within an age group, for feed eaten per day per animal, and for daily gains. There were no significant differences in size constant ratio studies. These were feed per day per 1000 pounds of animal maintained and feed eaten per unit of gain. Thus the indications were that within an age group the amount of hay eaten per 1000 pounds of body weight maintained was independent of the size of the animal. Likewise the economy of gain was independent of the size of the animal. For similar observations these hay feeding results tend to parallel those of the previous experiment in fattening steer calves of different sizes.

It was also possible to compare the effect of age on winter hay consumption in Hereford females. Heifer calves, full-fed, ate less per day than did bred yearlings or bred two-year-olds; similarly, full-fed bred yearlings ate somewhat less hay per day than did limited fed bred two-year-olds. Heifer calves gained somewhat less per day than bred yearlings, but the bred yearlings on full feed gained about the same as bred

two-year-olds on limited feed. Heifer calves ate significantly more hay per 1000 pounds of body weight than did the bred yearlings or the bred two-year-olds. The bred yearlings, full-fed, ate about the same amount of hay per 1000 pounds of body weight as did the limited-fed two-year-olds. There appeared to be a tendency for younger cattle to make more gain per pound of hay consumed than the older cattle. This was true in comparing calves vs. yearlings, calves vs. two-year-olds, and yearlings vs. two-year-olds.

The results of this experiment indicate that, within a given age group, total hay consumption and gains increased with size, but there were no significant differences in the amount of hay consumed per 1000 pounds of body weight maintained between Hereford females of large, intermediate, and comprest (small) sizes.

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SOME FACTORS AFFECTING GESTATION LENGTH AND BIRTH WEIGHT OF BEEF CATTLE[1]

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INFORMATION on factors influencing gestation length and birth weight is of interest to the practical animal husbandman as well as the animal breeder. The animal husbandman finds that birth weight is of economic importance and that a knowledge of factors influencing gestation length may be of value in planning herd management. The animal breeder is interested in factors affecting birth weight and gestation length so that he can adjust the data and secure more accurate heritability estimates of birth weight and gestation length. Then too, when the data are adjusted for known environmental effects, other influences on birth weight and gestation length can be more accurately studied.

The purpose of this paper was to study the influence of some of the factors which may affect the gestation length and birth weight of beef calves.

Materials and Methods

The data for this study were collected at the Nebraska Experiment Station at Lincoln from foundation animals used in the formation of the four lines of beef cattle which are being maintained at the station. The cattle were handled under typical eastern Nebraska farm conditions. They were on grass nearly the year round and received protein supplement during the winter. The level of nutrition was probably somewhat higher than that of average farm herds for the animals were maintained in good flesh at all times.

Records of sire, dam, date of breeding of dam, weight at birth, sex of calf, and date of calving were available for 502 calves, including 188 Hereford, 184 Angus, and 130 Shorthorns. These data were collected during the following years: Angus, 1932–1943; Hereford, 1935–1949; and Shorthorn, 1936–1949. Records in which estimates had been made of breeding dates or calf weights or where information was not complete were not used in this analysis.

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The inbreeding of the foundation cows and their calves used in this study has been quite low although many of the cows in each herd were related (relationships of 0.25 to 0.40 were common between contemporary animals).

The analyses of variance and covariance followed the methods given by Snedecor (1946).

Experimental Results and Discussion

Length of Gestation

Average gestation lengths for the three breeds together with their standard deviations are given in table 1. The Angus breed had the

TABLE 1. AVERAGE GESTATION LENGTHS AND STANDARD DEVIATION IN DAYS

Breed	Number of Gestations	Average Length	Standard Deviation
Angus	184	281.7	7.1
Hereford	188	286.1	5.6
Shorthorn	130	284.2	6.0
All breeds	502	284.0	14.4

shortest average gestation period, 281.7 days, while the Herefords had the longest, 286.1 days. In general the average gestation periods for these two breeds agree with previously published reports (Johnson, 1944; Livesay & Bee, 1945; and Warren, 1948). The present Angus figure, however, is considerably longer than the figure given by Gerlaugh, Kunkle, and Rife (1951). The 284.2-day average gestation period of Shorthorns is somewhat longer than most workers have reported.

The breed differences in average gestation length were significant at the one percent level, as shown by an analysis of variance. It seems that gestation length is a breed characteristic and that gestation lengths of animals of each breed fluctuate rather closely around the breed mean when pregnancy is normal.

Knapp, Lambert, and Black (1940), as well as others, found no significant trend between the length of first and subsequent gestation periods. Their results are substantiated by the present work. The intra-breed correlation between age of dam and gestation length was +0.078 which was not significant. The cows ranged in age from 2 to 11 years.

The influence of sex of calf on gestation length is shown in table 2.

The table shows that Hereford and Angus bull calves were carried for longer gestation periods than heifer calves, while the Shorthorn heifers were carried longer than the bull calves. The difference in gestation length of the sexes was significant only for the Angus breed. In other studies considerable variation in sex differences in gestation length has been found. Livesay and Bee (1945) found insignificant differences in gestation length due to sex in Angus and Herefords while Knapp *et al.* (1940) found a statistically significant 2.0-day difference between the sexes in beef Shorthorns.

Though a few sires seemed to have considerable effect on gestation length, the analysis of the data showed that within breeds, sire effects were not significant. Gerlaugh *et al.* (1951) indicated that sire as well as dam influenced gestation length.

Year effects, when studied on within breed-sex subclasses, were not significant. The interactions of sex and breed as determined in an

TABLE 2. AVERAGE LENGTH OF GESTATION PERIOD FOR MALE AND FEMALE CALVES, IN DAYS

Breed	Number of Days		Difference males—females
	Males	Females	
Angus	282.9±.6	280.7±.5	2.2
Hereford	286.8±.6	285.4±.5	1.4
Shorthorn	284.2±.8	284.3±.7	—.1
All breeds	284.7±.4	283.4±.4	1.3

analysis of variance did not have significant effects on length of gestation.

Birth Weight

The distribution of average birth weights with various lengths of gestation is given in table 3. A trend for larger birth weights with longer gestation lengths can be observed. The regression of birth weight of the calf (in pounds) on the length of gestation (in days) was +0.376. The partial regression of birth weight of calf on gestation length eliminating the effect of age of dam was +0.348. Both of these coefficients were highly significant. Knapp *et al.* (1940) found a correlation of +0.55 between birth weight and gestation length. The increase of +0.91 pound in birth weight of calf per day increase in gestation length reported by Braude and Walker (1949) is greater than the values found in the present study. Braude and Walker's result, however, is in close agreement with the increase of 0.91 pound per day

TABLE 3. MEAN BIRTH WEIGHT OF CALVES FOR VARIOUS LENGTHS OF GESTATION

Gestation lengths	Mean Birth Weights			
	Angus	Hereford	Shorthorn	All breeds
days	pounds	pounds	pounds	pounds
276–277	59.6	60.0	64.3	60.8
278–279	62.3	62.3	61.4	62.1
280–281	63.5	64.4	67.4	64.8
282–283	65.5	65.0	63.3	64.7
284–285	66.0	66.7	61.6	65.1
286–287	70.1	69.7	67.2	69.2
288–289	70.6	73.2	71.1	71.9
290–291	66.8	69.0	65.2	67.4

calculated from data presented by Jasper (1950) for calves carried for excessive periods past normal gestation length.

These observations indicate that growth of the calf in utero continues up to the actual time of birth at a nearly normal rate even though parturition does not occur until several days beyond the expected time. The physiological limits of the dam are apparently beyond the requirements of a normal calf, especially in nutrient supply and capacity of the reproductive organs.

Differences in gestation length accounted for 7.9 percent of the variance in calf weights. When the effect of age of dam was removed differences in gestation length accounted for 7.3 percent of the variance of calf weight.

The average birth weight of calves of each breed is given in table 4.

TABLE 4. AVERAGE BIRTH WEIGHT OF CALVES FOR EACH BREED AND SEX

Breed	Breed Average	Male	Female	Difference male–female	Difference adjusted for gestation length
	pounds	pounds	pounds	pounds	pounds
Angus	64.2	67.1±.95	61.8±.79	5.3	4.5
Hereford	67.4	69.9±.97	65.4±.82	4.5	3.9
Shorthorn	64.3	66.7±.26	61.8±.26	4.9	5.0
All breeds	65.4	68.0±.57	63.2±.51	4.8	4.3

The average birth weight of the Angus calves (64.2 pounds) roughly approximates most previously published figures for this breed (Rhoad, Phillips, and Dawson, 1945). The average birth weight of the Hereford calves, 67.4 pounds, was several pounds under the average reported by Gregory, Blunn and Baker (1950), Piam (1944) and Knapp, Baker, Quesenberry, and Clark (1942). They all reported average birth weights of 70 pounds or more. Most investigators (Dawson, Phillips, and Black, 1947) have reported average birth weights for Shorthorn calves heavier than the 64.3 pound average found in the present study. The differences between the mean birth weights of the Hereford and Angus

TABLE 5. AVERAGE BIRTH WEIGHT OF CALVES FROM COWS OF VARIOUS AGES

Age of cow at calving	Breed			
	Angus	Hereford	Shorthorn	Average
years	pounds	pounds	pounds	pounds
2–3	59.9	63.5	59.3	61.4
3–4	61.6	67.1	63.4	64.1
4–5	64.6	68.4	65.3	66.2
5–6	64.8	69.2	66.8	66.9
6–7	63.0	69.1	66.0	66.0
7–8	72.2	58.9	65.9	67.0
8–9	60.4	75.3	67.5	67.2
9–10	67.6	76.2	66.8	69.6
10–11	74.1	65.5	74.0	64.1
11–12	64.7	77.2	65.0	71.0

and Hereford and Shorthorn were statistically significant while the difference between the Angus and Shorthorn was not.

Table 4 also gives the mean birth weights of the bull and heifer calves of each breed. The bull calves consistently weighed more than the heifer calves. Highly significant differences between the birth weights of the sexes were found in all breeds. The birth weights were adjusted for differences in gestation lengths. This adjustment reduced the sex difference in the Angus and Hereford breeds but not the Shorthorn. About ten percent of the sex difference in birth weight is attributable to difference in gestation length of the two sexes. The sex differences found in these data strike about the average for the mean birth weights that have been reported heretofore.

The average birth weights of calves from cows in the various age groups of each breed are shown in table 5. The birth weights of the

calves from cows ten years old or older are not as reliable as the other weights because the number of cows in these age groups is small. The increase in birth weights of calves from three-year-old cows over two-year-old cows was much greater than the increase found between any other two consecutive years.

Braude and Walker (1949), Venge (1948), and Knapp *et al.* (1940) found that age of dam had an influence on the birth weight of the calf with the heaviest calves being born to relatively young cows, from four to six years of age. The present data, however, indicate that birth weights of calves from four- to six-year-old cows may not be as large as those from older cows.

The regression of birth weight of calf on age of dam was +1.043 pounds and the partial regression of birth weight on age was +0.970 pound in the multiple regression with length of gestation. These coefficients were highly significant.

These data indicate that, while a definite relationship exists between age of dam and birth weight of calf, the maximum birth weights of the calves are not reached until the cows are nine to ten years of age.

The work of Piam (1944) suggests that birth weights are not influenced by the bull. However, in the polyallele crosses of Angus and two breeds of *Bos indicus*, Rhoad *et al.* (1945) found quite definite sire effects upon the development and size of the calf at birth. In the present data sire effects were not statistically significant. One explanation for these varied results is that differences between sires within breeds are not great and their effects on birth weight are small.

Year effects on birth weight were not statistically significant. The relatively uniform conditions of management may have been a factor in causing the low variation in calf weights from year to year. The observation by Morrison (1948) that the mother is able to protect the unborn offspring to a certain extent against deficiencies in her food by drawing on stores in her own body may also be a partial factor in reducing variation in birth weight.

The paternal half-sib regression gave a heritability estimate of 0.22 for birth weight of calves. This is much lower than the latest value (0.50) given by Knapp and Clark (1950) for beef cattle. The present estimate is in closer agreement with the heritability estimates of 0.42 and 0.23 reported by Knapp and Nordskog (1946).

Summary

Data are presented on the influence of breed, age of dam, sex of calf, sire, years, and interaction of sex and breed on length of gestation in

beef cattle. The average gestation lengths for the three breeds studied were: Angus, 281.7 days; Hereford, 286.1 days; and Shorthorn, 284.3 days. The differences between the mean gestation lengths for the breeds were statistically highly significant. Bull calves tended to be carried longer than heifer calves. Within breeds the difference between the sexes was significant only for the Angus breed.

The influence of age of dam, sire, years, and breed-sex interactions on the length of gestation was not significant.

Data are also presented showing the effect of gestation length, breed, sex, age of dam, sire, years, and heredity on the birth weight of the calf. The birth weight of the Hereford calves was significantly larger than those of the Angus and Shorthorn calves. The difference between the Angus and Shorthorn birth weights was not significant. The regression of birth weight on gestation length was +.376 and was highly significant. A highly significant difference between the birth weights for the sexes was found. About 10 percent of the sex difference was due to differences in gestation length.

The data indicate that a definite relationship exists between age of dam and birth weight of calf and that the maximum birth weight is not reached until the cows are nine to ten years old. The regression of birth weight on age of dam was +1.04 and highly significant.

The effect of sires on birth weight was insignificant as were the year effects.

The paternal half-sib regression gave an estimate of heritability of 0.22 for birth weight.

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SEASONAL VARIATIONS IN THE FEED AND WATER INTAKE OF CATTLE

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IN a previous communication it was shown (Mullick, 1949) that the feeling of discomfort in animals due to climatic stress was closely associated with the decrease in the feed intake. Recently, Ragsdale, Brody, Thomson and Worstell (1948) observed that in a temperature controlled laboratory increasing ambient temperature rapidly depressed the feed consumption and milk production of cattle. Johnson and Kark (1947) have shown a striking correlation between the the daily average caloric intake and the mean environmental temperature in the U. S. armed forces.

In view of the significance of the relationship between the climatic conditions and feed requirements of animals, an investigation was undertaken to study the reaction of farm animals in tropical and sub-tropical conditions as obtained in this country. Mullick and Kehar (1951) recorded higher values for pulse rate, respiration rate and body temperature and lower values for body weight and hemoglobin with increasing air temperature. The most conspicuous changes were noticed in the respiration rate. The present article deals with the metabolic behavior of the different nutrients as affected by the seasonal rhythm prevailing in central northern India about 150 miles east of Delhi (Izatnagar, which is 28° 20′ north of the Equator and 79° 25′ east of the Prime Meridian). The maximum shade temperature in June sometime rises to 118°F. and in February it occasionally goes down to 35°F. The relative humidity varies from 40 to 90 percent in the months of June and August respectively.

Experimental

Six adult kumauni hill steers, apparently in good health, and similar in age, weight and general condition were selected for experimental purposes. In the absence of a temperature controlled laboratory, the observations were made in different seasons of the year, viz. summer, autumn, winter and spring. The experiment was arranged in such a way that the metabolic collections were made when extreme conditions of

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climate prevailed. Thus, the summer observations were made in June and the winter collections in February. The animals were fed on a ration consisting of eight pounds of wheat *bhoosa* as roughage and one pound of rape cake as concentrate. The animals were fed the concentrate before the roughage was offered. The residues of the concentrate and roughage were weighed separately during the metabolism periods. The animals were given a free choice of these feeds for ingestion all through the period of experimentation extending over 18 months. In winter months the animals took less of wheat bhoosa and more of rape cake, whereas, in the summer months the reverse was the case. Digestibility and water metabolism trials extended over a period of ten days in each season. Pulse rate, respiration rate, body temperature, air temperature and relative humidity were noted daily during the period of each trial. Body weights were taken from the average values before and after each trial.

Urine, feces and food were analysed by the methods of Talapatra, Ray and Sen (1940). The procedure adopted for recording pulse, respiration rate, body temperature, air temperature and moisture were the same as described by Mullick and Kehar (1951).

The figures were examined statistically according to Snedecor (1946) for the analysis of covariance in order to eliminate the effect of difference in body weight of the animals and the intakes of feed.

Results and Discussion

The range and the average values of air temperature, relative humidity, pulse rate, respiration rate, body temperature and body weight are given in table 1. It will be observed that the air temperature, pulse rate and respiration rate are higher in summer as compared with the other three periods, whereas relative humidity and body weight are definitely lower. The variations in body temperature (101.2–101.4°F.) in all the four periods do not seem to be significant. The relative humidity on the other hand is lowest in summer and maximum in autumn (33 and 81 percent respectively). The values for winter and spring lie within this range. The average body weight was maximum in winter. This confirms the previous observations of Mullick and Kehar (1951).

The details of the intake of water, ingestion of dry matter and urine voided are given in table 2. The water intake and the insensible perspiration seem to bear a direct relation with the increase in the atmospheric temperature, the values being 9.5 kg., 2.4 kg., 15.1 kg., and 8.0 kg. in winter and summer months respectively. The air temperatures were

TABLE 1. AIR TEMPERATURE, RELATIVE HUMIDITY, PULSE RATE, RESPIRATION RATE, BODY TEMPERATURE AND BODY WEIGHT IN DIFFERENT SEASONS[1]

	Air temperature 0° F.		Relative humidity %		Pulse rate per minute		Respiration rate per min.		Body temperature 0° F.		Body weight pounds	
Season	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Summer	84–110	98	28–40	33	49–64	58	30–56	43	101.0–101.4	101.2	336–382	359
Autumn	82– 93	88	78–84	81	49–62	55	37–51	41	100.9–102.0	101.2	347–423	383
Winter	54– 72	64	44–56	50	41–43	42	10–12	11	100.6–101.5	100.9	387–427	407
Spring	70–100	86	34–49	42	48–56	50	20–28	23	101.4–101.4	101.4	357–406	382

[1] Figures represent the average values of ten days observation on six animals in each season except body weight.

TABLE 2. METABOLISM OF WATER AND DRY MATTER

	Water intake[1] kg.		Insensible respiration kg.	Dry matter intake[1] kg.		Dry matter digested kg.	Ratio of water intake to dry matter		Urine volume ml.		Urine specific gravity	
Season	Range	Mean*		Range	Mean*		Intake	Digested	Range	Mean	Range	Mean
Summer	13.4–18.2	15.1	8.0	2.8–3.3	2.96	1.30	5.1	11.6	2201–2396	2254	1.036–1.040	1.038
Autumn	8.8–13.8	11.4	3.6	2.7–3.3	2.96	1.30	3.9	8.8	1928–2686	2315	1.034–1.041	1.037
Winter	8.5–11.2	9.5	2.4	2.8–3.5	3.09	1.48	3.1	6.4	2048–2767	2340	1.037–1.042	1.039
Spring	12.0–15.6	13.5	5.4	2.8–3.4	3.02	1.39	4.5	9.7	2106–2450	2280	1.036–1.041	1.038

[1] Water intake = water taken + water from feed + metabolic water.
* Differences between seasons significant at 5% level.

approximately the same in autumn and spring, but the humidity in the former season was almost twice that in the latter. The water intake and insensible perspiration were lower in autumn, the values being 11.4 kg. and 3.6 kg. respectively. The intakes of water and dry matter in different periods were examined statistically by the analysis of covariance. It has been found that the seasonal means of water and dry matter intakes differ significantly. The urinary output and specific gravity show very little change in the different periods studied. The ratios of water intake to dry matter intake and digestion were maximum in summer and minimum in winter, the values being 5.1, 11.6 and 3.1, and 6.4 respectively. When air temperature and relative humidity are studied in relation to water intake it is noticed that the amount of water consumed was more in the summer and the spring months and less in winter and autumn. These observations are in agreement with those by Thompson, Worstell and Brody (1949). From the high values of insensible perspiration shown by these animals, it appears that they possess a more efficient mechanism for regulating the body heat by evaporation through the skin. Thompson *et al.* have also pointed out that in summer months man with a large number of sweat glands requires more water and excretes less urine of increased specific gravity; whereas non-sweating cattle consume more water and excrete more urine of lower specific gravity. The Indian cattle consumed more water under summer conditions, whereas the urinary output and specific gravity remained almost unaffected as compared with the other three periods. These observations indicate that the Indian cattle occupy an intermediary position as regards the possession of sweat glands between man and foreign cattle. Further observations on this aspect are in progress.

The coefficient of digestion of the proximate principles in different seasons are given in table 3.

Analysis of covariance shows that the intakes of protein, fat and carbohydrate within the periods differed significantly.

It will be observed that the ingestion and digestion of protein are much less in summer (183 gm.) and autumn (183 gm.) as compared with winter (225 gm.) and spring (221 gm.) periods. The absolute amount of protein digested is also less in summer (71 gm.) and autumn (77 gm.) as compared with the other two periods (104 and 102 gm. respectively).

To give a true picture of the digestion of a particular element and also of the inter-relationship of the different nutrients digested an attempt has been made in calculating these results to find out if a relation exists between percentage of T.D.N. and the digestion of the element. It may thus be observed that the digested protein in terms of

TABLE 3. METABOLISM OF THE PROXIMATE PRINCIPLES[1]

	Protein					Fat					Total carbohydrates				
	Intake		Digested			Intake*		Digested			Intake		Digested		
Season	Range	Mean*	Amount	Coef.	% TDN	Range	Mean	Amount	Coef.	% TDN	Range	Mean*	Amount	Coef.	% TDN
Summer	164–205	183	71	39	4.71	54.0– 68.2	61	50	82	7.45	2338–2798	2500	1325	53	87.84
Autumn	173–193	183	77	42	5.45	73.7– 80.5	78	51	66	8.12	2204–2718	2441	1221	50	86.42
Winter	191–263	225	104	46	9.42	74.5–108.9	91	61	67	12.42	1728–2353	2054	863	42	78.15
Spring	209–246	221	102	46	6.84	76.0– 90.9	82	54	66	8.15	2305–2803	2486	1268	51	85.02

[1] Figures are the average values of ten days observations on six animals in each season.
* Differences between seasons significant at 5% level.

percentage of T.D.N. is less in the summer and autumn months. Best and Taylor (1949) pointed out that food, especially protein owing to its specific dynamic action, is an important factor in the chemical regulation of body temperature, for at high environmental temperature specific dynamic action of food acts counter to the physical mechanism which hastens heat loss. It appears from our observations that the lower intake of protein in the summer and autumn months helped the animals to produce less heat and shows that low protein diet is more suitable in hot weather for regulating the body temperature.

The intake of fat was minimum in summer (61 gm.) when the environmental temperature was maximum and highest in winter (91 gm.) when the air temperature was minimum. The figures for autumn and spring lie in between these two extremes (78 and 82 gm. respectively). It will be observed that though the coefficient of digestion of fat is maximum in the summer months, the amount of fat digested is comparatively low.

In studying the metabolism of carbohydrates it was interesting that the maximum intake of carbohydrates was in summer (3500 gm.) and minimum in winter (2054 gm.) The values for autumn and spring lie within this range. It is likely that the fats and carbohydrates were digested more in the summer months in view of their protein sparing activity. The higher coefficient of digestion of fat and its lower absolute amount digested may be due, as pointed out by Lusk (1923), to the relieving activity of fat in the elementary tract from the excessive digestion and absorption of carbohydrate. Besides, it is also likely that the higher coefficient of digestion of carbohydrates may help the animals to utilize fat in the feed more efficiently. The digestion of carbohydrates in the summer months appears to be associated with low heat production, specific dynamic action and calorigenic value.

From the above findings it may be concluded that the animals seem to adjust themselves to seasonal variations by changing the proportion of different food nutrients ingested. It may thus be inferred that feed is probably one of the important factors in regulating the heat mechanism of animals.

Summary

There seems to be little information on the metabolic behavior of ruminants in the tropics, affecting their general health and production. This investigation was designed to study the influence of seasonal rhythm on the metabolic behavior of different nutrients in cattle.

Observations on the pulse rate, respiration rate, body temperature,

body weight, digestibility and water metabolism were recorded on six healthy kumauni hill steers for summer, autumn, winter and spring seasons extending over a period of 18 months. Mean air temperature and relative humidity also were noted for the whole period of observation. It was found that:

(1) The pulse rate, respiration rate and body temperature increased while body weight decreased in the summer months.

(2) The amount of water taken and the insensible perspiration was highest in summer, comparatively lower in autumn and spring, and minimum in winter.

(3) The dry matter intake varied with the water intake.

(4) The urinary output and its specific gravity remained unaltered in all the periods.

(5) The ingestion of protein and fat is much lower in summer and autumn than in winter and spring.

(6) The amount of digested protein in terms of percentage of T.D.N. is less in summer and autumn months, whereas that of carbohydrate was higher in the summer months and the reverse was the case in winter and autumn.

(7) Differences in intake of water, dry matter and nutrients were statistically significant between the seasons.

(8) The interrelationship between the different nutrients and environmental conditions has been discussed.

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THE EFFECTS OF ENVIRONMENTAL TEMPERATURE AND RELATIVE HUMIDITY ON THE ACCLIMATION OF CATTLE TO THE TROPICS[1, 2]

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CLIMATIC conditions in the tropics are extremely variable and very different from those in Europe where many of the cattle breeds originated. In the tropics, climatic stress results from the operation of climatic factors such as air temperature, humidity, air movement, solar radiation and barometric pressure, acting singly or in combination. These may affect one or more of the physiological systems of the animal, there being evidence suggesting that the anterior pituitary, the adrenal and the thyroid are involved in reactions to thermal stress.

A number of workers have observed differences in tolerance to climatic stress with cattle from the different dairy and beef breeds. Gaalaas (1945) found a definite relationship between the air temperature, body temperature and respiration rate in Jersey cows. Seath and Miller (1947) made heat tolerance comparisons between Jersey and Holstein cows in Louisiana and found that the rate of increase of body temperature as a result of air temperature increase, was greater for Holsteins than for Jerseys, Holsteins having the higher maximum body temperatures.

Regan (1938) found in California that when the outdoor temperature is above 70° F. the rectal temperature of European cattle tends to increase. To a limited extent cattle can withstand this outside temperature by physical regulation. The upper limit of heat regulation in the producing cow is between 80° and 85° F., depending on the breed. Temperatures above 85° F. have detrimental effects on cattle. When cattle of European breeds are kept at temperatures above 85° F. for more than 24 hours, body temperature rises. When above the critical temperature for a longer period a pyrexial condition develops and later, anorexia develops and milk flow declines.

[1] The data in this paper are taken from a thesis submitted by the senior author to the Graduate School of The Pennsylvania State College in partial fulfillment of the requirements for the Ph.D. degree.

[2] Authorized for publication on March 1, 1951 as paper number 1661 in the Journal series of the Pennsylvania Agricultural Experiment Station.

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Regan (1938) reported that humidity does not appear to be a factor in the comfort of dairy cows, except when approaching saturation, probably above 95 percent relative humidity. Seath and Miller (1945) have reported that high humidity is not harmful to cows. They report that changes in humidity have no appreciable effect on respiration rate. Rhoad (1936) believes that air high in moisture content may increase metabolism by lowering the rate of evaporation of water from the lungs.

Manresa (1940) found that the hemoglobin of Holstein cattle in the Philippines is significantly lower than that of Holsteins in the United States.

Ragsdale and associates (1948, 1949) report that the optimum temperature for maximum milk production appears to be not far from 50° F. The critical high temperature is apparently 80° F. Rising temperatures are most detrimental to Holstein cows. The depressing effect of high temperature is much greater for high than for low milking cows. The larger the cow the more sensitive it is to rising environmental temperature. The critical high temperature at which the depressing effect on milk production, feed consumption and on body weight becomes evident is 75° to 80° F. for Holstein cattle, and 80°–85° F. for Jersey cattle. On reducing the temperature to 50° to 60° F. the feed consumption and milk production promptly returned to normal. At 105° F. both practically stopped. The decline in milk production and feed consumption is more pronounced for Holsteins than for Jerseys. The greater sensitiveness of Holstein cattle to higher environmental temperature is shown not only by their greater rate of decline in milk production, feed consumption and body weight, but also by a greater rate of increase in rectal temperature and respiratory activities. Their greater sensitiveness is not due to breed as such but rather to their greater body weights. The amount of body surface per unit body weight decreases with increasing body weight, and the rate of heat dissipation per unit weight must decrease with consequent steeper rises in body temperature in large animals, as compared to smaller ones.

Basherov (1950) after analyzing the records of the purebred Guernsey herd of the College of Agriculture in Puerto Rico has found that with respect to milk production, reproduction, breeding efficiency and growth rates, the Guernsey breed is well adapted to subtropical conditions.

Experimental Procedure

This study was undertaken for the purpose of observing the behavior of European breeds of cattle in the Caribbean area. The observations

were made on different farms located in different climatic areas on the island of Puerto Rico.

Environmental temperature and relative humidity were considered as two of the most important factors involved in acclimatization. The criteria used as measures of the metabolism and condition of the cattle were body temperature, respiratory rate, pulse rate, hemoglobin percentage and milk production.

Data were taken during the four seasons of the year. Every three months, on a specified day which was selected as representative of the respective season, complete data were taken measuring the behavior of the cattle under observation on each particular farm. During two years over 134 head of cattle were studied on different farms situated in different climatic areas on the island of Puerto Rico. The records of 93 of these cows were used in the study of the dairy breeds and 41 cows in the study of the beef breeds.

Environmental air temperature and relative humidity were determined by means of a Taylor humidiguide. Body temperature was determined per rectum with a standard clinical thermometer. Respiratory rate was determined by counting flank movements per minute, the animal being under shade. Pulse rate was determined by counting heart beats per minute using a veterinary stethoscope. Hemoglobin was determined with a Spencer hemoglobinometer. Milk produced on the day of observation was weighed with a standard milk scale.

Data for each season were taken regularly at the same time of the day, which was always in the early afternoon.

The results were subjected to study by the method of multiple correlation employing the abbreviated Doolittle method based on Laplace's development of a determinant. The principal factors studied were the environmental temperature and the air humidity. The dependent factors were body temperature, respiratory rate, pulse rate, hemoglobin and milk production.

The results pertaining to milk production were subjected to an analysis of variance.

Results

In judging the metabolism of the experimental cattle the following values were considered as normal: 101.0° F. to 101.5° for body temperature, 15 to 30 respirations per minute, and 45 to 65 heart beats per minute. The atmospheric conditions prevailing during the two years, were normal for this area and the data present a good picture of the expected behavior of imported breeds of cattle under these climatic conditions. (table 1)

TABLE 1. SUMMARY OF AIR TEMPERATURE, RELATIVE HUMIDITY, BODY TEMPERATURE, RESPIRATION RATE, PULSE RATE, BLOOD HEMOGLOBIN, AND MILK PRODUCTION OF THE DAIRY BREEDS (PUERTO RICO)

	No. of Cows	Oct. 1947 to Sept. 1948 Range	Mean	Oct. 1948 to Sept. 1949 Range	Mean	Two Year Mean & Standard Error
Air Temperature (°F.)		75–92	85.3	75–94	84.0	84.6 ±0.22
Relative Humidity (%)		55–75	62.6	54–76	65.0	63.8 ±0.53
BODY TEMPERATURE (°F.)						
Holstein	22	101.0–105.6	102.51	101.2–105.5	102.11	102.31±0.12
Guernsey	30	101.0–105.0	102.14	101.0–106.0	102.06	102.10±0.06
Brown Swiss	21	101.0–104.5	102.05	101.0–104.6	101.97	102.01±0.06
Jersey	10	101.5–103.8	101.96	101.4–103.2	101.81	101.88±0.05
Ayrshire	10	101.2–103.0	102.01	101.2–103.3	102.08	102.04±0.04
RESPIRATORY RATE PER MIN.						
Holstein	22	36–88	57.1	28–80	50.4	53.7 ±1.45
Guernsey	30	36–88	58.6	28–80	49.3	53.9 ±1.48
Brown Swiss	21	32–80	55.1	28–80	49.5	52.3 ±0.85
Jersey	10	32–68	54.2	32–60	43.6	48.9 ±0.56
Ayrshire	10	40–80	51.0	32–80	47.5	49.2 ±1.32
PULSE RATE PER MIN.						
Holstein	22	32–90	54.3	28–92	43.0	48.6 ±0.85
Guernsey	30	38–88	55.7	24–84	41.6	48.6 ±0.57
Brown Swiss	21	32–80	53.8	24–68	43.7	48.7 ±0.72
Jersey	10	38–80	55.1	24–80	46.9	51.0 ±0.75
Ayrshire	10	36–60	44.5	28–80	40.8	42.6 ±1.24

TABLE 1. SUMMARY OF AIR TEMPERATURE, RELATIVE HUMIDITY, BODY TEMPERATURE, RESPIRATION RATE, PULSE RATE, BLOOD HEMOGLOBIN, AND MILK PRODUCTION OF THE DAIRY BREEDS (PUERTO RICO)—*Continued*

	No. of Cows	Oct. 1947 to Sept. 1948 Range	Mean	Oct. 1948 to Sept. 1949 Range	Mean	Two Year Mean & Standard Error
BLOOD HEMOGLOBIN (Grams per 100 ml.)						
Holstein	22	5.0–9.0	7.0	4.5–9.5	6.8	6.9 ±0.11
Guernsey	30	4.0–10.0	7.1	4.5–9.0	6.5	6.8 ±0.14
Brown Swiss	21	6.5–8.5	7.5	4.5–9.0	6.8	7.1 ±0.34
Jersey	10	4.5–8.5	7.5	5.5–8.5	6.7	7.1 ±0.10
Ayrshire	10	5.0–8.0	6.9	6.0–8.0	6.7	6.8 ±0.08
DAILY MILK PRODUCTION (lbs.)						
Holstein	22	4.4–35.2	15.0	4.4–33.0	13.7	14.3 ±1.30
Guernsey	30	4.4–33.0	13.9	2.2–32.9	15.8	14.8 ±0.98
Brown Swiss	21	3.0–28.0	15.3	6.0–35.0	14.5	14.9 ±0.81
Jersey	10	6.0–29.0	18.5	5.0–27.0	12.7	15.6 ±0.74
Ayrshire	10	6.6–30.8	19.7	8.8–26.4	16.3	18.0 ±0.45

For the two years studied, there was a mean air temperature of 84.6±0.2° F. and 63.8±0.5 percent relative humidity. Considering the five dairy breeds studied, under the same environmental conditions, the Jersey breed presented the most normal body temperature of 101.9± 0.1° F., the lowest respiratory rate of 48.9±0.6, the highest pulse rate with 51.0±0.8, the highest blood hemoglobin with 7.1±0.1 grams per 100 ml. of blood, and the second highest milk production.

The Brown Swiss breed followed with a body temperature of 102.0± 0.1° F., a respiratory rate of 52.3±0.9, a pulse rate of 48.7±0.7 beats per minute, the highest blood hemoglobin with 7.1±0.3 grams hemoglobin per 100 ml. of blood and was third in milk production.

The Ayrshire breed had a body temperature of 102.0±0.04° F., the second lowest respiratory rate with 49.2±1.3 beats per minute, the lowest pulse rate with 42.6±1.2 beats per minute, the lowest blood hemoglobin with 6.8±0.1 grams per 100 ml. of blood and ranked highest in milk production.

The Guernsey breed had the second highest body temperature with 102.1±0.1° F., the highest respiratory rate with 53.9±1.4 respirations per minute, the second lowest pulse rate with 48.6±0.6 beats per minute, the lowest blood hemoglobin with 6.8±0.1 grams per 100 ml. of blood and the second lowest milk production.

The Holstein breed had the highest body temperature with 102.3± 0.1° F., the second highest respiratory rate with 53.7±1.4 respirations per minute, third highest pulse rate with 48.6±0.9 beats per minute, second lowest blood hemoglobin with 6.9±0.1 grams per 100 ml. of blood and the lowest milk production. (table 1)

Temperature and Humidity Effects

Correlations between the various factors under consideration were determined as stated above and tested for significance by the *t* test. On the basis of this analysis, it is indicated that within the limited range of air temperature variations encountered in this study, significant increases in body temperature may occur in the Guernsey and Ayrshire breeds as the result of increase in air temperature. The data indicate that the body temperature of cattle of the Holstein, Jersey and Brown Swiss breeds was not affected significantly by increases in air temperature.

With increases in the environmental temperature, significant increases in the respiratory rates of the Holstein and Guernsey breeds are indicated but higher air temperatures did not appear to affect the respiratory rates of the Jersey, Brown Swiss and Ayrshire cattle.

The pulse rate of the Guernsey cattle appeared to be increased as the result of increase in air temperature, but this effect was not observed with the Holsteins, Jerseys, Brown Swiss and Ayrshires.

Hemoglobin appeared to be lower in the blood of the Holstein cattle as the result of increased air temperature, but this effect was not apparent with the other breeds studied.

Body temperature, respiratory rate, pulse rate, blood hemoglobin and milk production with the Guernsey, Brown Swiss, Jersey and Ayrshire breeds do not appear to be significantly affected by the variations in relative humidity encountered in this study. In general, it can be said that relative humidity did not appear to be a significant factor affecting the physiological well-being of the dairy breeds, with the exception, possibly, of Holsteins.

The above discussion has concerned the possible single effects of temperature and humidity changes. The authors feel that the data are informative for this purpose. It is recognized, however, that the combined effects of these factors are probably more important and that unobserved variables attending the temperature and humidity changes, may also play a role in influencing the physiological changes observed.

An analysis of variance shows a significant difference in milk production between the dairy breeds. The mean two-year milk production was higher with the cattle of the Ayrshire, Jersey, Guernsey and Brown Swiss breeds as compared to the Holsteins observed in this study. On the basis of average daily milk production the Holsteins fell below the cattle of the other breeds when length of dry period is taken into consideration. This was unexpected, as it is generally assumed that the Holstein is the highest milk yielder under Puerto Rican conditions. However, when their rather long dry periods are taken into consideration the average production of this breed is less.

The high respiration rates observed in this study probably indicate an effort of the dairy breeds to maintain their normal body temperature under high ambient temperature by increasing their heat dissipation. This condition was noticed especially in cattle of the Guernsey and Brown Swiss breeds. High respiration rates probably explain in part the superiority of certain breeds in their ability to dissipate heat at high temperature. (table 1)

Three beef breeds were studied along with the dairy breeds using the same procedure and methods of analysis. The three breeds studied were Native grade cows, Brahman grade cows, and Hereford cows, Native and Brahman grade cattle being the most important in the Puerto

Rican beef cattle industry. The Hereford breed has been recently introduced on a large scale and is still under field trial.

The body temperatures, respiratory rates, and pulse rates of the Native and Brahman grade cattle were lower, and the blood hemoglobin values higher than those of the Hereford cattle studied. This indicates that Native and Brahman grades acclimate better than do Hereford cows to the tropical environment. (table 2)

The environmental temperature prevalent during the two-year period apparently did not affect significantly the body temperature, respiratory rate, pulse rate or blood hemoglobin of any of the three beef breeds studied. (table 2)

Contrary to the behavior of cattle of the dairy breeds, cattle of the three beef breeds studied appeared to be affected by the air humidity. An increase in relative humidity resulted in a significant increase in body temperature in the Native grades and in the Hereford cows, and a significant decrease in the Brahman grades. This may indicate that, under the conditions of this study and with the methods of sampling used, humidity might be a significant factor in causing climatic stress in the beef breeds studied. The difference between the dairy and the beef breeds in their reaction to a high humidity might be explained by the anatomical difference between the dairy and beef types. The dairy type is lean and angular as compared to the rotund beef type. Lean and angular animals expose more body surface than rounded animals. A greater body surface in turn affects greater heat dissipation. Thus from this point of view dairy type animals might be better adapted than beef type animals to a tropical environment.

Conclusions

The differences in the body reactions and physiological well being between cattle of the five dairy breeds studied indicate breed differences which are important from the viewpoint of acclimatization and milk production:

1. The Jersey breed is readily adaptable to Puerto Rican climate and environment. The Brown Swiss, Guernsey and Ayrshire breeds seem to follow the Jersey in adaptability in this order, as shown by their body reactions and milk production. The Holstein breed from the physiological viewpoint seems to be less adaptable than the other breeds to Puerto Rican climate and environment.

2. Native grades, Brahman grades and Hereford cows seem to accli-

TABLE 2. SUMMARY OF AIR TEMPERATURE, RELATIVE HUMIDITY, BODY TEMPERATURE, RESPIRATION RATE, PULSE RATE, AND BLOOD HEMOGLOBIN OF THE BEEF BREEDS STUDIED (PUERTO RICO)

	No. of Cows	Oct. 1947 to Sept. 1948 Range	Mean	Oct. 1948 to Sept. 1949 Range	Mean	Two Year Mean & Standard Error
AIR TEMPERATURE (°F.)		75–92	84.5	78–94	85.2	84.8 ±0.72
RELATIVE HUMIDITY (%)		55–75	62.6	54–70	63.0	62.8 ±0.52
BODY TEMPERATURE (°F.)						
Native Grades	20	101.0–105.6	102.12	101.0–105.5	101.90	102.01±0.10
Brahman Grades	11	101.0–105.6	102.14	101.0–105.0	101.93	102.03±0.18
Hereford Breed	10	101.5–105.5	101.83	102.0–105.5	103.14	102.48±0.15
RESPIRATORY RATE PER MIN.						
Native Grades	20	32–76	50.4	28–72	46.2	48.3 ±0.71
Brahman Grades	11	28–80	57.2	28–80	52.3	54.7 ±2.09
Hereford Breed	10	44–80	59.0	36–72	52.3	55.6 ±3.64
PULSE RATE PER MIN.						
Native Grades	20	32–90	53.2	28–60	39.4	46.3 ±0.73
Brahman Grades	11	32–90	50.2	24–60	45.7	47.9 ±1.30
Hereford Breed	10	48–80	57.1	32–52	43.3	50.4 ±0.75
BLOOD HEMOGLOBIN (Grams per 100 ml.)						
Native Grades	20	6.0–9.0	7.47	5.0–10.5	6.63	7.05±0.10
Brahman Grades	11	6.0–8.5	7.54	5.0–9.0	6.80	7.17±0.08
Hereford Breed	10	5.5–8.0	6.59	5.0–9.0	6.80	6.69±0.07

mate well to Puerto Rican conditions but seem to be more sensitive to a high humidity than the dairy breeds studied.

3. There seems to be nothing in the Puerto Rican environment to prevent the further development of the cattle breeds, if suitable methods of feeding, management and protection against disease and parasites are employed. The selection of cattle with high tolerance to thermal stress is of primary importance as the basis for the full development of the cattle industry in the tropics.

4. Environmental temperature appears to be the most significant factor affecting the physiological well being of the cattle breeds, relative humidity being of secondary importance.

5. The results of this study should be applicable to areas with a similar climate and environment, and especially to regions with a maritime or insular climate in the Caribbean area.

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A RESPIRATION APPARATUS FOR C^{14} STUDIES WITH COWS[1]

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LONG term respiration trials for measuring carbon balances in cattle were started over half a century ago when Kühn (1894) constructed an apparatus of the Pettenkofer type for steers, with which Kellner conducted his classical studies on feed utilization. Later similar apparatuses were built. Most used among these were the respiration calorimeter at Pennsylvania State College (Armsby and Fries 1903, Armsby 1904), the respiration chamber for cows at Copenhagen (Möllgaard and Anderson 1917), and the California respiration apparatus for cows (Kleiber 1935).

For short term trials a Regnault-Reiset type of respiration apparatus with a tracheal canula was used by Zuntz. For trials in man, mouth pieces with noseclips and later face masks replaced tracheotomy. (See Krogh 1916 p. 39). Brody (1928) adapted such face masks for short term respiration trials with farm animals by the closed system. Kibler (1948) modified Brody's apparatus to an open air circulating system.

The apparatus described here involves a face mask with pneumatic adapter designed and constructed by M. Edick. This mask is sufficiently tight yet comfortable enough for trials of three hours duration. It allows the cows to ruminate during the trial. Absolute tightness is not essential since the apparatus operates with open air circulation. The apparatus is designed to obtain samples for gas analysis, (taken by a specially constructed sampler). Representative samples of the expired CO_2 can be taken frequently enough for the measurements of the radioactivity in the expired CO_2 as a function of time after injection of C^{14} labeled compounds into the cow. This information is important for determining the rate of metabolism of these compounds and of their utilization in the formation of animal products such as milk.

Description

General Arrangement. Figure 1 is a schematic sketch of the apparatus. The cow inhales air through eight inlet valves (V_1) of face mask (M)

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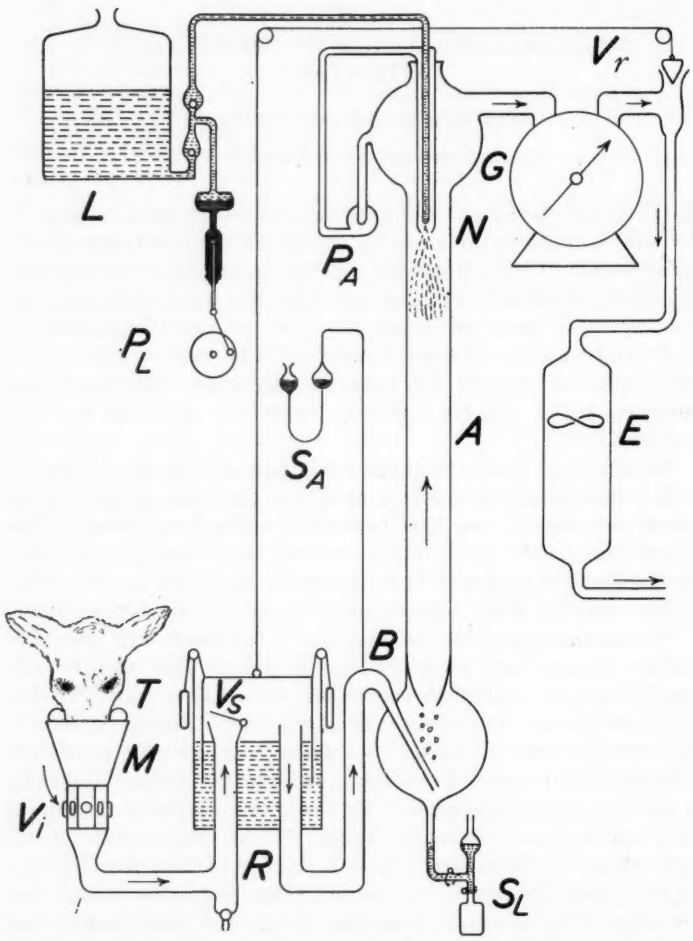

Figure 1. Respiration apparatus for measuring carbon balances in cattle. (A) absorbing tower, (B) position in air duct where composite gas sample is taken, (E) vacuum cleaner, (G) gas meter, (L) storage tank with normal NaOH solution, (M) gas mask, (N) spray gun, (P_A) air pump for spray gun, (P_L) pump for NaOH solution, (R) spirometer, (S_A) gas sampler, (S_L) measuring device for collected NaOH spray, (T) inner tube, (V_i) air inlet valves in gas mask, (V_r) valve to regulate ventilation by vacuum cleaner (V_s) air inlet valve of spirometer.

and exhales through valve (V_s) into the spirometer (R). From the spirometer the expired air flows into the lower flask of the CO_2 absorption tower (A). It rises through the tower against a spray of NaOH solution and leaves through a testmeter (G) and a vacuum cleaner (E).

Mask. The mask is made of 20 gauge galvanized iron in the form of two funnels connected by an octagon prism as shown in figure 1. The upper, wider, end of the funnel contains an inner tube, ordinarily used for scooter wheels, with 6 inches inside and 12 inches outside diameter. Each of the eight rectangles forming the prism is provided with a circular flutter valve ordinarily used in gas masks of the armed services. The mask for our cow has thus eight times the capacity of the army gas mask.

Ventilating System. Two flexible tubes of 5 cm. inside diameter, later to be replaced by one tube of 7.5 cm. inside diameter, connect the mask to the spirometer.

The spirometer is made of a galvanized iron ash can with two, 2 inch pipes soldered to the bottom as indicated in figure 1. A bell 36 cm. in diameter and 20 cm. in height, made of monel metal, is balanced in the can by four counter weights hanging from pulleys which are mounted on the rim of the can. Two of these pulleys carry chains which compensate for the change in buoyancy resulting from more or less immersion of the bell in the water of the spirometer. Valve (V_s) consists of a circular plate 14 cm. in diameter perforated by four holes each of about 4 cm. in diameter. This plate is covered with a rubber sheet fastened in the center. This arrangement allows free passage of air from the mask to the spirometer and effectively blocks air movement in the opposite direction. A vacuum cleaner (E) sucks air through the absorbing tower (A) and the testmeter (G).

A valve (V_r) regulates the ventilation rate. It consists of a conical hardwood block which fits into one outlet of a 2 inch pipe tee and is operated by the movement of the spirometer bell as indicated in figure 1. When the spirometer is empty the bell, being at its lower position, lifts the conical block out of the seat in the tee. In this condition, the vacuum cleaner sucks air directly from outside through the open tee and none through the gas meter. When subsequently the cow expires air into the spirometer, raising the bell, the valve block is lowered into its seat and closes the tee. The vacuum cleaner now sucks air through the gas meter and the absorption tower and thus empties the spirometer. The spirometer bell is sucked down and in turn lifts the block of valve (Vr) opening the tee again to outside and consequently stopping the suction through the respiration apparatus.

This arrangement prevents resistance to the cow's breathing and at the same time keeps the total ventilation at a low rate which is desirable for the accuracy of a respiration trial based on gas analysis.

CO_2 Absorbing System. The CO_2 is absorbed by normal NaOH. This solution is stored in container (L) as indicated in figure 1. At present two, 20 liter bottles are used. They will be replaced by a stainless steel tank of 60 liters capacity. A displacement pump (P_L) drives the NaOH solution into a painter's spray gun (N) at the rate of 125 ml. per minute (in earlier trials the rate was 250 ml. per minute). A blower (P_A) sucks air from the upper flask of the absorber and pumps it back through the spray gun. The spray of NaOH solution thus produced, absorbs the CO_2 from the expired air moving through the tower in the opposite direction. The NaOH solution is finally collected at the lower end of the tower and measured into sampling bottles (S_L).

Gas Sampler. Before the expired air enters the absorption tower a sample of it is taken at (B) and collected at (S_A) at the rate of 5 ml. per minute.

Figure 2 is a detailed sketch of the gas sampler. A 1/32 HP electric motor drives a worm and gear speed reducer which operates the oscillator (O) at a frequency of one cycle per minute. Figure 2 shows the phase of lowering the leveling bulb (LP) of mercury pump (P) which during this phase sucks in a sample of air from the air current (B) through a small bubbler (D) (with concentrated H_2SO_4 as drying agent) and the open mercury capillary valve (V_i). When the mercury in pipette (P) reaches its lowest position the slider (SO) of the oscillator turns the triangular suspension for the leveling bulbs of the mercury valves. This motion raises the leveling bulb of the inlet valve (V_i) closing this valve; it lowers the bulb of outlet valve (V_e) and thus opens this valve. The subsequent raising of the leveling bulb (LP) forces mercury into pipette (P) and thus pumps the air sample from that pipette to collector (C) which contains mercury. The leveling bulb of the collector (LC) hangs on a wheel (K) mounted on a shaft which turns in ball bearings. A spiral (SP) is bolted to the wheel. A counter weight (W) is suspended from that spiral. When a gas sample enters the collecting cylinder (C) it drives some mercury from (C) to the leveling bulb (LC). The resulting increase in weight of this bulb turns the wheel and spiral until the resulting increase of the lever for the suspension of the weight (W) just compensates for the increase in weight of the leveling bulb. The spiral is so constructed that equilibrium is established just when the surface of the mercury in the leveling bulb, open to outside air, is at the same level as the mercury surface in the

collecting bulb. This arrangement keeps the gas pressure in the collecting bulb always equal to the barometric pressure. This new form of gas

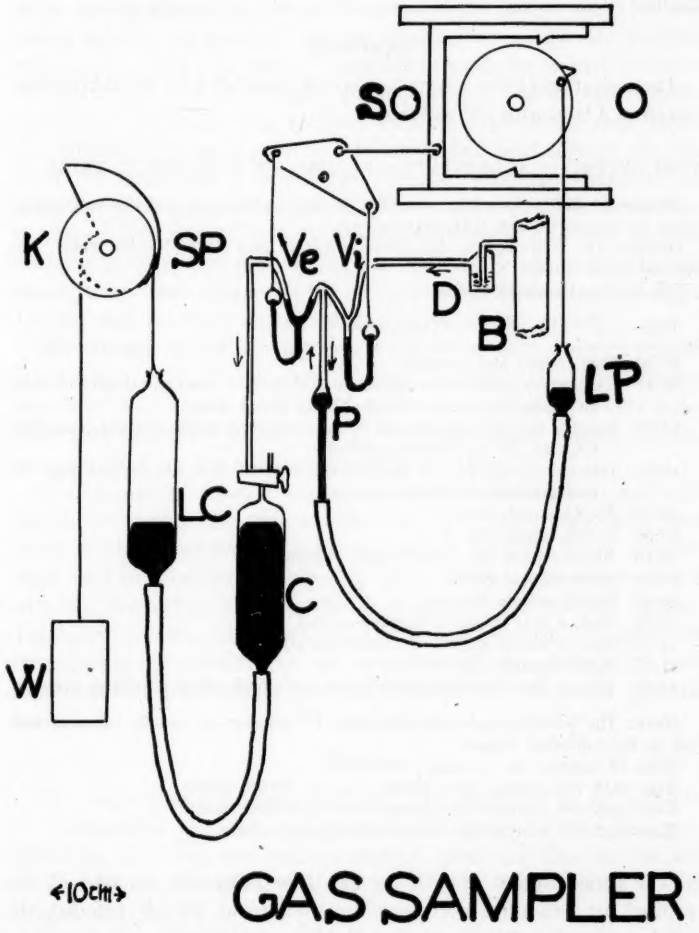

Figure 2. Gas Sampler. (B) main air duct, (C) gas collecting tube, (D) H_2SO_4 bubbler to dry gas sample, (K) wheel on which leveling bulb is suspended, (LC) leveling bulb of gas collector, (LP) leveling bulb of gas pump, (O) oscillator, (P) pipette of gas pump, (SO) slider of oscillator which operates valve supporter, (SP) spiral on which counter weight is suspended, (V_e) outlet valve of gas pump, (V_i) inlet valve of gas pump, (W) counter weight of gas collector.

collector is more compact, transportable, and also more reliable than the collecter based on Archimedes' principles described earlier (M. Kleiber 1935).

Operation

The operation of the apparatus may be illustrated by an abbreviated record of a trial with C^{14} as tracer.

TABULATION 1: ABBREVIATED RECORD OF CARBONATE TRIAL IV

October 12, Jersey Cow 880, weighing 525 Kg., lactating, brought to metabolism room to familiarize her with surroundings.

October 13, 8:30 o'clock, Spaghettis inserted into both jugular veins (see Ralston *et al.* 1949).

October 14, Respiration Trial:

Time	Operation
09:20	Cow milked and urinated.
09:42	Respiratory mask on, respiration trial started, vacuum cleaner started, air pump for spray started, NaOH pump started.
10:00	Injected into left jugular vein 20 ml. of isotonic saline solution containing 6.58 mc. C^{14} as sodium carbonate.
10:01	Injected 30 ml. of 1% Evans blue solution into left jugular vein for measurement of plasma volume.
10:02	NaOH sample No. 1.
10:04	NaOH sample No. 2.
10:16	Blood sample No. 1 from right jugular vein.
10:29	Blood sample No. 2.
10:30	NaOH sample No. 14.
10:58	End of first period of respiration trial.
11:55	End of second period of respiration trial.
12:57	NaOH sample No. 44.
13:00	End of third period of respiration trial, mask off, cow milked, urinated.

NOTE: The NaOH samples for measuring C^{14} activity are usually taken according to the following scheme:

Take all samples up to sample No. 20.
Take each 2nd sample up to sample No. 30, discard others.
Take each 3rd sample up to sample No. 40, discard others.
Take each 4th sample for rest of trial, discard others.

The concentration of CO_2 in the three composite samples of the expired air and three corresponding samples of the air entering the mask are analyzed in a modified Haldane apparatus.

The amount of CO_2 absorbed by the spray is measured by titration with a mixed indicator of cresol red and thymol blue (Kleiber 1935 p-38).

The C^{14} in the expired CO_2 is measured by counting the number

of disintegrations from a 2.5 cm. disc of $BaCO_3$ prepared by outgassing the NaOH samples taken at the lower end of the absorption tower. After testing various procedures to prepare the $BaCO_3$ disc, the following method was adapted. Ten ml. of the spray sample are acidified with H_2SO_4, while CO_2 free air is sucked through the system, bubbling through a solution containing 2 milliequivalents NaOH and 4 milliequivalents of $BaCl_2$. The solution contains thymol blue and cresol red to indicate when 1 millimol of $BaCO_3$ has been formed. At this point the outgassing is terminated and the precipitate deposited on a circular filter paper as a disc of 2.54 cm. diameter. This precipitate is washed with alcohol, dried and weighed to make sure that the disc contains at least 140 mg. of $BaCO_3$. Preliminary measurements had demonstrated that changes in the amount of $BaCO_3$ on the disc above 140 mg. had no effect on the number of counts per minute.

The amount of 140 mg. $BaCO_3$ on a 2.54 cm. disc means a sample "thickness" of 28 mg. per cm^2. A curve "counted activity vs. sample thickness" in Calvin's book on isotopic carbon (Calvin, 1949) indicates that the choice of 140 mg. as minimal amount $BaCO_3$ for our counting involves a considerable margin of safety.

From a sample of $Na_2C^{14}O_3$, for which we are indebted to the U. S. Bureau of Standards, various dilutions with inert carbonate were made to obtain samples with known specific activity. These samples were used to establish a calibration curve relating number of counts with our method to specific activity in microcuries per mol carbon. This curve in turn allows one to read directly specific C^{14} activities from counts per minute. For our measurements, we are using a flow counter with helium bubbling through heptane at 0° C. as the quenching gas.

Results

The major results of the respiration trial described as an example are summarized in table 1. To obtain the figures for the CO_2 produced by the cows one has to subtract from the CO_2 in the air stream the amount which comes from outside (0.03 percent in the inhaled air).

This CO_2 from outside makes the specific C^{14} activity of the CO_2 absorbed in the spray about 2 percent lower than the specific activity of the expired CO_2. A similar dilution effect on the radio activity is produced by the amount of carbonate already present in the NaOH solution before it absorbs CO_2 from the current of respired and out-

TABLE 1. RESPIRATION TRIAL WITH LACTATING COW (CARBONATE TRIAL IV)

1	2	3	4	5	6	7	8
Time	Ventilation Air Vol.	CO_2 Conc. in Comp. Gas Sample After Cow	CO_2 in Air Current per Hour	CO_2 Absorbed in NaOH Spray (Titration)	Efficiency of CO_2 Absorption in Spray	CO_2 Entering System with Outside Air per Hr. 0.3×(2)	CO_2 Produced by Cow per Hr. (4)—(7)
hr.	M^a(s)	%	liter(s)	liter(s)	%	liter(s)	liter(s)
10	8.63	1.429	123	50.8	41	3	120
11	8.57	1.580	135	56.8	42	3	132
12	7.64	1.619	124	55.1	44	2	122
13							

(s) Signifies that the gas volumes are reduced to standard conditions namely 0° centigrade, 760 mm. pressure and dryness.

side air. For the trial described, this carbonate already present in the NaOH solution amounted to 9 percent of the carbonate absorbed.

In this special case, therefore, the specific activity of the expired CO_2 was 11 percent (2+9) higher than that in the CO_2 outgassed from the collected sample of the NaOH spray.

Figure 3 shows the relation of the relative specific activity in the expired CO_2 (in microcuries per mol carbon per unit of the injected

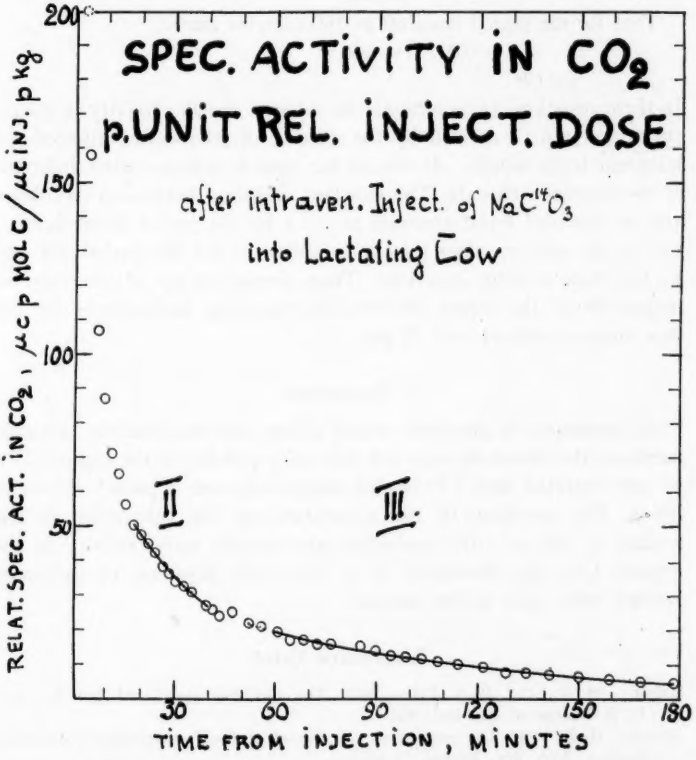

Figure 3. Relation of relative specific activity in the expired CO_2 and the time after injection of C^{14} carbonate into the bloodstream of the lactating cow.

II. Second period of trial: Used for calculating curve 20 to 40 minutes after injection.

III. Third period of trial: Used for calculating curve 60 to 180 minutes after injection.

dose in microcuries injected per kilogram body weight), and the time after injection of the C^{14} labeled carbonate into the bloodstream of a lactating cow. The solid curves indicate regression lines calculated under the assumption that the decrease of the C^{14} activity in CO_2 may be expressed as a series of first order processes.

The regression equation for the period from 20 to 40 minutes after the injection is as follows:

$$\gamma = 46e^{-0.028\ (t-20)}$$

That for the period from 60 to 180 minutes reads:

$$\gamma = 19e^{-0.012\ (t-60)}$$

In these equations (γ) expresses the value of specific activity in microcuries per mol C, divided by the number of microcuries injected per kilogram body weight. (t) stands for time in minutes after injection of the labeled carbonate. The standard deviation between a calculated and an observed result amounts to ± 1.1 for the period II on figure 3 (20 to 40 minutes after injection) and to ± 0.5 for period III (60 to 180 minutes after injection). These deviations are of the order of magnitude of the errors involved in measuring radioactivity by the flow counter method with Q gas.

Summary

An apparatus is described which allows the simultaneous measurements of the metabolic rate and the radio activity in the expired CO_2 of cows injected with C^{14} labeled compounds over a period of several hours. The operation of the apparatus and the calculation of the results, as rate of CO_2 production and specific radio activity of the expired CO_2 are illustrated by a trial with injection of carbonate labeled with radio active carbon.

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STABILITY OF CAROTENE IN MIXED FEEDS[1]

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IN a previous publication it was shown that certain feed ingredients may affect the stability of carotene in alfalfa when the latter is mixed with each ingredient (Mitchell and Silker, 1950). In most of that study the alfalfa constituted 50 percent of the mixtures. In a practical feed mixture the alfalfa content would be much less than this. Also, the carotene would be subjected to the combined effect of several ingredients. Hence, it seemed desirable to study the stability of carotene in mixed feeds when the feeds contained the amount of alfalfa which ordinarily may be present in such a feed.

Experimental Procedure and Results

The Departments of Animal Husbandry, Dairy Husbandry, and Poultry Husbandry of the Kansas Agricultural Experiment Station have basal rations containing no alfalfa meal for use in studying vitamin A and carotene metabolism. Dehydrated alfalfa meal was added to each of these rations so that it constituted 10 percent of the final feed mixture. The samples were mixed thoroughly and were stored in loosely capped fruit jars at 25° C. A sample of the alfalfa meal was included for comparison. Also included was a mixture of 10 percent alfalfa meal in glucose (cerelose) to achieve dilution of the alfalfa meal similar to that in the rations without increasing the stability of the carotene (Mitchell & Silker, 1950). Carotene determinations were made before storage and at intervals thereafter by the method of Silker, Schrenk, and King (1944). The method was modified for the mixtures by using a 10-gm. sample and 100 ml. of extracting solvent. The carotene concentration of the final solutions was measured at 4360 A with a Beckman spectrophotometer.

The composition of each of the feeds after the addition of the alfalfa is shown in table 1. The carotene destruction which occurred during storage is presented in table 2.

It will be seen from the data that the carotene was appreciably more stable in most of the mixtures than it was in the undiluted alfalfa. The stability of the carotene of the pig and dairy 3 rations

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TABLE 1. PERCENTAGE COMPOSITION OF EXPERIMENTAL RATIONS

Ingredient	Ration						
	Pig	Dairy 1	Dairy 2	Dairy 3	Calf	Laying Mash	Broiler
Alfalfa	10	10	10	10	10	10	10
Ground Corn	73	14.5	24.3	35	23	31	58.5
Soybean Meal (Solvent)	13	29.4	15.3	17.5	20	25	29.2
Wheat Bran	—	29.4	24.3	26.4	23	—	
Ground Oats	—	14.7	24.3	8.8	23	10	
Wheat Shorts	—					18.5	
Yeast	1.35						
Steamed Bone Meal	0.15	1.0	1.0	1.0	0.6	3	0.9
Dried Skim Milk	2.25						
NaCl	0.15	1.0	1.0	1.3	0.6	0.5	0.5
$CaCO_3$	0.15					2	0.9
$MnSO_4$ (gm./100 lbs.)	—					25	25
Vitamin Supplement (gm./100 lbs.)	—					70	85

was particularly good, while that of the laying mash was not greatly different from the undiluted alfalfa. Dilution of the alfalfa with cerelose resulted in somewhat greater carotene destruction than occurred in undiluted alfalfa. This was especially noticeable during the first five weeks of storage, but on longer storage the over-all losses in the diluted and undiluted alfalfa samples were similar.

In order to determine the source of improved stability in these mixtures, each ingredient was studied separately. Alfalfa meal again constituted 10 percent of the final mixture. The feed ingredient was

TABLE 2. CAROTENE DESTRUCTION IN MIXED FEEDS DURING STORAGE AT 25° C.

Ration	Carotene Destroyed (%)				
	Weeks in Storage				
	2.5	5	8	12	16
Dehydrated Alfalfa Meal	11	24	46	61	68
Cerelose + 10% Alfalfa Meal	21	42	55	67	73
Dairy 1	12	21	28	40	56
Dairy 2	10	20	32	45	54
Dairy 3	11	16	21	29	39
Calf	15	23	32	46	62
Pig	9	13	16	24	32
Laying Mash	12	22	32	51	70
Broiler	6	12	20	29	41

added at one or more levels in the range in which it normally is added to a feed. Cerelose was used as the diluent to complete the mixture. The samples were stored at 25° C. and analyzed at intervals. The composition of the mixtures and the carotene destruction which occurred during storage are shown in table 3.

TABLE 3. EFFECT OF FEED INGREDIENTS ON DESTRUCTION OF CAROTENE WHEN ALFALFA MEAL CONSTITUTED 10 PERCENT OF THE MIXTURE AND CERELOSE WAS THE DILUENT

Ingredient	Composition of Mixture			Carotene Destruction (%)		
	Ingredient	Alfalfa	Cerelose	Weeks in Storage at 25° C.		
				4	9	14
	%	%	%			
None	0	100	0	19	42	55
None	0	10	90	33	50	58
Cottonseed Meal (solvent)	15	"	75	19	34	42
" " "	30	"	60	16	30	36
Soybean Meal (solvent)	15	"	75	28	48	53
" " "	30	"	60	27	44	49
Yellow Corn Meal	15	"	75	19	31	40
" " "	60	"	30	12	16	27
Oats	10	"	80	23	42	60
"	20	"	70	21	41	50
Wheat Bran	10	"	80	20	34	40
" "	20	"	70	18	33	38
Dried Brewers Yeast	2	"	88	21	40	46
Dried Skim Milk	2.5	"	87.5	30	47	56
Mineral Mixture						
Calcium Carbonate	1					
Steamed Bone Meal	1	"	87	30	47	54
Iodized Salt	1					
Trace Mineral Mixture						
Manganese Sulfate	0.05					
Copper Sulfate	0.05	"	89.8	32	52	56
Cobalt Chloride	0.05					
Ferrous Sulfate	0.05					

The ingredients which were studied varied considerably in their ability to inhibit carotene destruction. Ground yellow corn exhibited the greatest stabilizing effect, and was especially active when it constituted 60 percent of the mixture. Solvent-extracted cottonseed meal had some stabilizing effect. Little additional benefit was obtained by

increasing the concentration of the latter from 15 to 30 percent. Solvent-extracted soybean meal had only slight activity. Ground oats showed some activity at the end of four weeks of storage, but after nine weeks its ability to protect the carotene of the alfalfa was exhausted. Ten percent of wheat bran was as effective as 15 percent ground corn. However, increasing the amount of bran in the mixture to 20 percent did not result in additional carotene retention. Dried brewers yeast at a 2 percent level exhibited slight activity, while dried skim milk was devoid of activity.

The addition of various minerals did not alter the rate of carotene destruction under the conditions of this experiment. This is interesting in view of the suggestion (Halverson and Hart, 1948) that such minerals as copper, manganese, and iron may contribute to carotene destruction in mixed feeds.

Discussion

The manner in which feed ingredients exert their influence on the carotene in alfalfa meal is not clear. A possible explanation is that antioxidants which are present in the feed ingredients diffuse into the alfalfa meal, perhaps by way of the fat present in the ingredients. Previously it was found (Mitchell and Silker, 1950) that solvent meals were without stabilizing activity when mixed in a 1:1 ratio with alfalfa meal, while expeller meals were good stabilizers. This may indicate the importance of the fat, or it may only mean that the extracted meals have had most of the natural antioxidants removed. It may be argued that the added ingredients contain easily oxidized substances which deplete the oxygen surrounding the alfalfa particles, or that they surround the alfalfa particles with material more impervious to oxygen than alfalfa meal itself. Since the sample jars were not full, and the samples were mixed thoroughly at each analysis, a reduced oxygen supply around the alfalfa particles probably is not the explanation. Further investigation will be needed to determine the nature of the stabilizing effect. The practical importance of the effect is readily apparent, however.

Summary

Carotene stability was greater in feeds containing 10 percent alfalfa than in undiluted alfalfa. The individual ingredients of the feeds varied in their ability to stabilize carotene when mixed with alfalfa and cerelose. Ground yellow corn and wheat bran possessed the greatest

stabilizing activity. Dried brewers yeast, solvent-extracted cottonseed meal and ground oats had some activity. Dried skim milk and solvent-extracted soybean meal were ineffective. The addition of various minerals, including copper, cobalt, iron, and manganese, did not increase carotene destruction.

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THE PREDICTION OF DIGESTIBILITY FOR FEEDS FOR WHICH THERE ARE ONLY PROXIMATE COMPOSITION DATA[1]

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THE authors in a former publication (Schneider *et al.*, 1951) presented sets of equations to estimate the digestibility of individual samples of feed, taking proximate composition into account. These equations are applicable to feeds for which there has been a sufficient number of digestion trials to establish fairly accurate mean values. A problem arises, however, as to the best method of predicting digestion coefficients for feeds on which insufficient or no digestibility data are available. The present paper gives equations for this purpose.

Procedure

The form of the general equation to predict digestion coefficients for kinds of feeds with only proximate composition data is the same as that previously presented (Schneider *et al.*, 1951). The partial regression coefficients used in the previous case, however, were fitted on a "within-feed" basis. (In this article the earlier equations will be referred to by the term "within-feed.") In the present case, the fitting was done on a "between-feeds" basis, but was done separately for each major class of feeds. The classes were essentially the same as those used previously, but, in some cases, a further division into two subclasses, high and low protein, was made. In general, this separated the legume and non-legume feeding stuffs. This was done so that the assumption of a linear relationship between digestibility and composition (which theoretically is not true for protein and fat digestibility) will not lead to excessively divergent predicted values. This subdivision was not necessary in fitting the within-feed regression coefficients, because within-feed variation in composition is not nearly so great as is between-feed variation in composition.

For the present purposes it is more convenient to write the equa-

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tion previously used (Schneider *et al.*, 1951) in simpler form, as follows:

$$Y=C+b_1X_1+b_2X_2+b_3X_3+b_4X_4 \qquad \text{(Eq. 1)}$$

In this equation, C is a constant for the nutrient and the feed-class subdivision under consideration; b_1, b_2, b_3, and b_4 are partial regression coefficients, and X_1, X_2, X_3, and X_4 are the moisture-free percentages of crude protein, crude fiber, nitrogen-free extract, and ether extract, respectively, for the sample of feed for which it is desired to estimate the digestibility. Only three of the four organic nutrients determined in proximate composition are utilized as predictors. This was done for the same reasons as presented in the previous article for within-feed equations.

Results and Applications

The constants and partial regression coefficients calculated for the several nutrients in each feed class are given in tables 1, 2, and 3 for cattle, sheep and swine, respectively.

TABLE 1. PARTIAL REGRESSION COEFFICIENTS FOR PREDICTING DIGESTION COEFFICIENTS AND TOTAL DIGESTIBLE NUTRIENTS OF FEEDS ON WHICH THERE ARE FEW OR NO DATA ON DIGESTIBILITY FOR *CATTLE*

Predictors	Predictand				
	Crude protein	Crude fiber	N-F.E.	Ether extract	T.D.N.
	High Protein Hays (Over 13 percent protein)[1]				
Constant	302.2	383.0	198.7	−139.5	163.6
Protein %	2.078	−6.730	1.015	omit	−1.077
Fiber %	−3.266	−3.315	−2.671	.808	−1.567
N-F.E. %	−3.973	−3.031	−1.435	2.214	−.960
Ether Extract %	omit	omit	omit	30.835	omit
	Low Protein Hays (Under 13 percent protein)				
Constant	95.1	215.8	240.4	−9.4	200.8
Protein %	1.150	−2.489	−.346	omit	−1.182
Fiber %	−.409	−2.820	−3.208	−.959	−2.616
N-F.E. %	−.869	−.891	−1.396	.825	−.949
Ether Extract %	omit	omit	omit	19.784	omit

[1] All percentages are on a moisture-free basis.

TABLE 1. Continued

Predictors	Predictand: Crude protein	Crude fiber	N-F.E.	Ether extract	T.D.N.
Dry Roughages other than Hays					
Constant	−283.3	313.8	197.6	−123.8	146.8
Protein %	6.072	3.431	4.393	omit	4.461
Fiber %	3.339	−3.213	−2.038	1.061	−1.470
N-F.E. %	3.410	−3.275	−1.929	2.851	−1.367
Ether Extract %	omit	omit	omit	.452	omit
Forages Cut and Fed Green					
Constant	−140.2	−73.6	441.8	23.0	−84.3
Protein %	4.694	2.284	−3.908	omit	2.607
Fiber %	2.994	1.579	−4.357	.393	1.679
N-F.E. %	1.302	1.459	−4.330	.255	1.485
Ether Extract %	omit	omit	omit	2.729	omit
Silages					
Constant	−82.3	397.9	100.0	−15.9	212.7
Protein %	3.227	−5.874	−.293	omit	−2.351
Fiber %	1.634	−3.976	−.978	.280	−2.196
N-F.E. %	1.057	−3.242	−.031	.933	−1.245
Ether Extract %	omit	omit	omit	8.645	omit
High Protein Concentrates (Over 18 percent protein)					
Constant	4.7	18.2	3.8	77.1	−16.6
Protein %	1.233	.691	.487	omit	.992
Fiber %	.755	.700	−.783	−.040	omit
N-F.E. %	.626	−.769	1.771	.262	1.119
Ether Extract %	omit	omit	omit	.364	2.170
Low Protein Concentrates (Under 18 percent protein)					
Constant	62.0	336.6	207.5	−124.0	181.8
Protein %	.821	−2.372	−4.791	omit	−4.500
Fiber %	1.200	−4.299	−.027	4.647	omit
N-F.E. %	−.204	−3.611	−.884	2.161	−.680
Ether Extract %	omit	omit	omit	2.524	.584

An example of the application of equation 1 is as follows: It is desired to estimate the digestibility for cattle of the fiber in a sample of feed which is non-descript except that it is a hay containing 6.5 percent protein, 34.2 percent fiber, 47.4 percent N.F.E. and 2.1 percent fat on a moisture-free basis. The constant and the regression coefficients from table 1 in the crude fiber column for low-protein hays and the above composition figures are substituted into equation 1 to obtain:

$$Y=215.8-2.489(6.5)-2.820(34.2)-.891(47.4)=61.9$$

The reader should be careful to use the within-feed regression coefficients given in the former publication whenever dealing with

TABLE 2. PARTIAL REGRESSION COEFFICIENTS FOR PREDICTING DIGESTION COEFFICIENTS AND TOTAL DIGESTIBLE NUTRIENTS OF FEEDS ON WHICH THERE ARE FEW OR NO DATA ON DIGESTIBILITY FOR *SHEEP*

Predictors	Predictand				
	Crude protein	Crude fiber	N-F.E.	Ether extract	T.D.N.
	High Protein Hays				
	(Over 13 per cent protein)[1]				
Constant	−31.8	137.4	30.8	−3.5	−0.2
Protein %	2.478	−1.788	1.025	omit	.993
Fiber %	1.392	−1.514	.370	−.821	.181
N-F.E. %	.398	−.303	.197	1.143	.854
Ether Extract %	omit	omit	omit	9.854	omit
	Low Protein Hays				
	(Under 13 percent protein)				
Constant	72.2	238.8	43.6	195.6	54.2
Protein %	2.425	−1.331	.463	omit	.531
Fiber %	−.806	−2.195	−.264	−3.019	−.322
N-F.E. %	−.343	−2.006	.447	−1.551	.159
Ether Extract %	omit	omit	omit	9.902	omit
	Dry Roughages other than Hays				
Constant	70.6	187.0	109.6	−33.5	60.9
Protein %	1.618	−4.196	−.546	omit	−.705
Fiber %	−1.905	−1.668	−.973	.582	−.348
N-F.E. %	.039	−.931	−.363	.883	.138
Ether Extract %	omit	omit	omit	8.113	omit

[1] All percentages are on a moisture-free basis.

TABLE 2. Continued

Predictors	Predictand: Crude protein	Crude fiber	N-F.E.	Ether extract	T.D.N.
High Protein Forages Cut and Fed Green					
(Over 17 percent protein)					
Constant	100.4	164.0	162.8	108.4	159.0
Protein %	.500	—.348	—1.091	omit	—1.077
Fiber %	—.393	—3.805	—1.245	—1.038	—1.675
N-F.E. %	—.592	—.081	—.853	—1.246	—.779
Ether Extract %	omit	omit	omit	4.817	omit
Low Protein Forages Cut and Fed Green					
(Under 17 percent protein)					
Constant	132.1	112.4	81.9	—44.3	63.3
Protein %	.583	—.436	1.014	omit	—.522
Fiber %	—1.155	—1.292	—1.038	2.086	—.205
N-F.E. %	—.853	—.235	.136	—.147	.287
Ether Extract %	omit	omit	omit	18.643	omit
High Protein Silage					
(Over 15 percent protein)					
Constant	155.8	54.2	228.3	154.9	104.3
Protein %	—.247	—.011	—2.924	omit	—.687
Fiber %	—.753	—.368	—1.228	—1.779	—.420
N-F.E. %	—1.730	.275	—2.079	—1.683	—.604
Ether Extract %	omit	omit	omit	4.685	omit
Low Protein Silage					
(Under 15 percent protein)					
Constant	101.8	99.0	76.7	—86.9	20.7
Protein %	.256	.998	.035	omit	.392
Fiber %	—.911	—1.155	—.782	—1.053	.368
N-F.E. %	—.580	—.295	.250	1.959	.584
Ether Extract %	omit	omit	omit	22.659	omit
High Protein Concentrates					
(Over 28 percent protein)					
Constant	113.8	—176.5	26.7	26.7	11.2
Protein %	—.389	1.925	.201	omit	.650
Fiber %	—.811	4.255	—.079	1.740	omit
N-F.E. %	—.171	2.615	1.156	.392	.967
Ether Extract %	omit	omit	omit	2.412	1.324

TABLE 2. Continued

Predictors	Predictand: Crude protein	Crude fiber	N-F.E.	Ether extract	T.D.N.
	Low Protein Concentrates (Under 28 percent protein)				
Constant	54.0	—27.4	11.8	315.4	26.5
Protein %	2.109	—.604	.310	omit	.248
Fiber %	—.342	1.720	.742	—12.087	omit
N-F.E. %	—.171	.962	.863	—2.971	.655
Ether Extract %	omit	omit	omit	11.888	.977

feeds for which there are available sufficiently reliable average digestion coefficients. The material given in this paper is *only* for the purpose of estimating digestion coefficients and total digestible nutrient con-

TABLE 3. PARTIAL REGRESSION COEFFICIENTS FOR PREDICTING DIGESTION COEFFICIENTS AND TOTAL DIGESTIBLE NUTRIENTS OF FEEDS ON WHICH THERE ARE FEW OR NO DATA ON DIGESTIBILITY FOR *SWINE*

Predictors	Predictand: Crude protein	Crude fiber	N-F.E.	Ether extract	T.D.N.
	High Protein Concentrates (Over 21 percent protein)[1]				
Constant	124.8	71.8	—373.0	105.4	12.4
Protein %	—.578	—1.292	5.562	omit	.516
Fiber %	—.516	1.477	4.839	10.638	omit
N-F.E. %	—.116	.728	4.357	—6.145	1.011
Ether Extract %	omit	omit	omit	—.535	2.609
	Low Protein Concentrates (Under 21 percent protein)				
Constant	31.6	1024.7	—92.4	—162.9	—143.1
Protein %	2.258	—13.839	2.641	omit	2.752
Fiber %	—1.484	—15.256	—.362	3.240	omit
N-F.E. %	.302	—9.839	1.954	1.946	2.395
Ether Extract %	omit	omit	omit	16.204	2.691

[1] All percentages are on a moisture-free basis.

tents for feeds on which few or no digestibility data are available. The estimates given by the present equations are not as accurate as the estimates based on within-feed regression. This is because the between-feed variation in digestibility is only partly accounted for by variation in proximate composition (Schneider *et al.*, 1950). Nevertheless the estimates obtained by the present equations are good approximations when digestibility data are lacking on the feed of interest.

Summary

Equations have been presented for estimating the digestion coefficients of crude protein, crude fiber, nitrogen-free extract, and ether extract and the content of total digestible nutrients in feeds for which few or no digestibility data are available. The percentage composition of crude protein, crude fiber, nitrogen-free extract, and ether extract are used as predicting factors. The present equations should be distinguished from those given in a previous publication which were designed for use with feeds on which sufficient digestibility data are available. As present equations do not yield as precise estimates, the former equations should be used whenever they apply.

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RESPONSE OF GROWING-FATTENING PIGS TO BACITRACIN, AUREOMYCIN AND OTHER SUPPLEMENTS[1]

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SINCE the isolation of vitamin B_{12} (Rickes *et al.*, 1948), Nesheim *et al.* (1950) using a "synthetic milk" diet reported the quantitative vitamin B_{12} requirement of the baby pig to be approximately 20 mcg. per kg. of dry matter in the diet. Investigations concerning the quantitative vitamin B_{12} requirement of growing-fattening pigs have been reported by Richardson *et al.* (1950) and Vohs *et al.* (1951). Jukes *et al.* (1950) reported a growth promoting effect from the addition of crystalline aureomycin to weanling pig rations. Numerous reports have appeared in the literature concerning the value of crude and pure sources of vitamin B_{12} and various antibiotics added singly and in combination to rations for poultry and swine.

Very little information has been reported regarding the value of bacitracin in swine or poultry rations. Matterson and Singsen (1951) found that the addition of approximately 3 mg. of bacitracin per pound of a practical-type chick-starting ration promoted an 11 to 12 percent increase in weights at 8 weeks of age. In the same tests the addition of about 4.5 mg. of aureomycin per pound of ration increased weights at 8 weeks by 7 to 11 percent.

The investigation reported herein was conducted in two phases: In phase 1 (growing-fattening pigs in drylot, weaning to 100 lb. live weight) the objectives were (1) to study the effect of adding 0.125 percent vitamin B_{12} feed supplement[4] to a "corn-solvent soybean oil meal" ration which included additions of minerals, vitamins A and D and riboflavin, pantothenic acid, niacin and choline (see table 1), (2) to ascertain the value of adding 5 mg. bacitracin (furnished by pharmaceutical grade bacitracin or by an antibiotic [bacitracin] feed supplement) or 5 mg. crystalline aureomycin hydrochloride per pound

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[4] A dried fermentation product (Proferm-6) obtained by culturing unidentified non-pathogenic microorganisms on a media adapted for microbiological production of vitamin B_{12} activity and guaranteed to contain not less than 6 milligrams of vitamin B_{12} activity per pound.

of the basal ration plus 0.125 percent vitamin B_{12} feed supplement and (3) to compare the supplementary effect of 0.125 percent of the above vitamin B_{12} feed supplement and 3 percent condensed menhaden fish solubles as additions to the basal ration plus an antibiotic (bacitracin) feed supplement.

TABLE 1. COMPOSITION OF BASAL RATIONS

Ingredients	Weaning to 100 lb.	100 to 200 lb.
	Percent	
Ground yellow corn	64.3	78.9
Solvent soybean oil meal	32.5	17.8
Steamed bone meal	1.0	1.0
Mineral mixture (H & K)[1]	2.0	2.0
Viadex (5000 I.U. vitamin A and 1000 I.U. vitamin D per gram)	0.2	0.2
B-vitamin additions[2]	+	+
Vitamin B_{12} feed supplement[3]	—	0.125

[1] Mineral mixture reported by Dyer *et al.* (1950) JOURNAL OF ANIMAL SCIENCE 9:281.
[2] 150 mg. riboflavin, 500 mg. calcium pantothenate, 500 mg. niacin and 100 g. choline chloride powder (25% choline chloride) were added per 100 pounds of ration.
[3] A dried fermentation product (Proferm-6) obtained by culturing unidentified non-pathogenic microorganisms on a media adapted for microbiological production of vitamin B_{12} activity. Guaranteed to contain not less than 6 milligrams of vitamin B_{12} activity per pound.

In phase 2 (growing-fattening pigs in drylot, 100 to 200 lb. live weight) the purpose was to investigate the influence of time and duration of the addition of bacitracin to the basal ration on rate of gain and certain physical carcass characteristics.

Experimental Procedure

Six comparable lots of ten 56-day-old Chester White and Duroc pigs were self-fed a 20 percent crude protein corn-solvent soybean oil meal ration in drylot from weaning to 100 pounds liveweight. They had been raised to weaning by sows fed adequate rations on bromegrass pasture and had been given access to creep rations. The pigs were bedded with wood shavings, confined in pens with concrete floors and given water ad libitum. The basal ration as shown in table 1 was altered or supplemented as follows: Lot 1, basal ration; Lot 2, basal ration plus 0.125 percent vitamin B_{12} feed supplement; Lot 3, same as Lot 2 plus 5 mg. crystalline aureomycin hydrochloride per pound of basal ration; Lot 4, same as Lot 2 plus pharmaceutical grade bacitracin to furnish 5 mg. bacitracin per pound of ration; Lot 5, same as Lot 2 plus 0.05 percent antibiotic feed supplement containing

10 g. bacitracin per pound (furnished 5 mg. bacitracin per pound of ration); and Lot 6, same as Lot 5 except that 3 percent condensed menhaden fish solubles replaced 0.125 percent vitamin B_{12} feed supplement.

To investigate the influence of time and duration of bacitracin feeding upon rate of gain and upon certain carcass characteristics, the pigs in Lots 2 and 4 were continued on test to a weight of 200 pounds. The pigs in Lots 2 and 4 were subdivided into two groups of five pigs each. Each pig was allotted to phase 2 of this study on the weigh day that it weighed approximately 100 pounds. The ration fed to Lot 2 in phase 1 was altered to contain 15 percent crude protein and became the basal ration for phase 2 (see table 1). Lots 2A and 4A were fed the basal ration; whereas Lots 2B and 4B were fed the basal ration plus pharmaceutical grade bacitracin (5 mg. bacitracin per pound of ration).

Each lot of five pigs was housed in a 6′ x 8′ individual house located on an outside concrete floored pen. The pigs were bedded with straw, watered in troughs and had access to the ration in a self-feeder. One pig in each lot gained quite slowly. Gain and carcass data are presented for the four apparently normal pigs in each lot.

Each pig was removed from the test and slaughtered on the weigh day that it most nearly approximated 200 pounds in live weight. The carcasses were held in a cooler at 32° F. for approximately 48 hours before carcass weights and back fat measurements at the 1st thoracic, 13th thoracic and 1st lumbar vertebrae were taken.

Results and Discussion

Phase 1 (weaning to 100 lb. in drylot). The results of this phase of the investigation are briefly summarized in table 2. The pigs fed the basal ration plus the vitamin B_{12} feed supplement (Lot 2) gained 17 percent faster and consumed 6 percent less feed per unit of gain than pigs fed the basal ration (Lot 1). The difference in average daily gain between the two lots was not statistically significant. The high intra-lot variance in Lot 1 as compared with the other lots might be accounted for by differences in body stores of individual pigs at the start of the test. The superiority of rate of gain by pigs in Lot 2 over Lot 1 occurred mainly during the last half of the experimental period. This suggests that the pigs response to the vitamin B_{12} supplement did not occur until pigs had depleted their body stores of the nutrient(s) furnished by the vitamin B_{12} feed supplement.

TABLE 2. RESPONSE OF WEANLING PIGS FED A 20% CRUDE PROTEIN CORN-SOLVENT SOYBEAN OIL MEAL RATION IN DRYLOT TO BACITRACIN, AUREOMYCIN AND OTHER SUPPLEMENTS (1950–51)

Items Compared	Lot Numbers and Treatments					
	1	2	3	4	5	6
	Basal Ration	Basal Plus 0.125% Vitamin B_{12} Feed Supplement [1]	(2) Plus Aureomycin Hydrochloride [2]	(2) Plus Pharmaceutical Grade Bacitracin [3]	(2) Plus Bacitracin Feed Supplement [4]	(1) Plus 3% Cond. Menhaden Fish Solubles [5] Plus Bacitracin Feed Suppl.
Number of pigs	10	10	10	10	10	10
Av. initial weight, lb.	32	32	32	32	33	32
Av. final weight, lb.	89	98	101	100	101	100
Av. daily gain, lb.—and standard error	0.86±.10	1.01±.04	1.28±.04**	1.17±.05*	1.15±.07*	1.17±.05*
Av. daily feed per pig, lb.	2.62	3.02	3.48	3.35	3.31	3.44
Feed per 100 lb. gain, lb.	321	302	274	291	296	300

* Average daily gain of lots 4 and 6 over lots 1 and 2 was significant ($P<0.05$) and lot 5 was significant ($P<0.05$) over lot 1.
** Average daily gain of lot 3 over lots 1 and 2 was highly significant ($P<0.01$).
[1] See footnote 3, Table 1.
[2] Donated by Lederle Laboratories, Pearl River, New York.
[3] Bacitracin Lot composite No. 8 (35 units per milligram) furnished by Commercial Solvents Corporation, Terre Haute, Indiana. Calculated to contain 77.8% pure bacitracin.
[4] Contained approximately 10 grams of bacitracin per pound. Donated by Commercial Solvents Corporation, Terre Haute, Indiana.
[5] Donated by Central Soya Company, Inc., Decatur, Indiana. Contained 52.7% solids, 36.33% crude protein and a pH of 4.6.

The addition of 5 mg. crystalline aureomycin hydrochloride per pound of ration (Lot 3 vs. Lot 2) resulted in a 27 percent increase in average daily gain (highly significant) and a 9 percent reduction in feed consumed per unit of gain. Terrill and Krider 1950 reported that the addition of 25 mg. aureomycin hydrochloride per pound of a similar "corn-soybean oil meal" ration promoted a 28 percent increase in the daily gain of weanling pigs fed to 100 pounds live weight in drylot.

The addition of 5 mg. bacitracin, supplied by pharmaceutical grade bacitracin (Lot 4 vs. Lot 2) resulted in a 16 percent increase in daily gains (significant). The response from pharmaceutical grade bacitracin and from bacitracin feed supplement when each furnished 5 mg. bacitracin per pound of ration did not differ significantly (Lot 5 vs. Lot 4). Thus, the bacitracin feed supplement apparently did not furnish factors in addition to those supplied by the Lot 2 ration plus pharmaceutical grade bacitracin.

Additions of 0.125 percent vitamin B_{12} feed supplement and 3 percent condensed menhaden fish solubles to the basal ration plus 0.05 percent antibiotic (bacitracin) feed supplement were equally effective in promoting rate of gain (Lot 6 vs. Lot 5).

The addition of an antibiotic to the ration (Lots 3–6) increased daily gains and average daily feed consumption in all cases. However, the amount of feed consumed per unit of gain was not appreciably reduced with the exception that the pigs receiving aureomycin consumed 9 percent less feed per unit of gain than pigs in Lot 2. Feces were observed to be firmer throughout the test in Lots 3 through 6 than in Lots 1 and 2.

Phase 2 (100 lb. to 200 lb. in drylot). Pigs receiving bacitracin in the ration throughout the entire period from weaning to market weight gained significantly faster during each period (phase 1 or phase 2) and for the entire period on test than did pigs fed the basal ration (vitamin B_{12} feed supplement included) throughout. The gains of pigs in Lot 2B (bacitracin supplementation beginning at 100 lb.) and in Lot 4A (bacitracin supplementation ceased at 100 lb.) did not differ significantly from gains made by pigs in Lot 2A (basal lot). Although the number of pigs on each treatment of phase 2 is small, the data suggest that for best results bacitracin should be included in the ration for the entire period from weaning to market weight.

Berg *et al.* (1950) studied the effect of adding and deleting an aureomycin fermentation product from the diet of 4½-week-old chicks. They reported that deleting the aureomycin product from the ration

resulted in a cessation of the accelerated growth response observed during the first 4½ weeks of life when the test material was fed. They further reported that adding the aureomycin product to the ration at 4½ weeks of age caused an immediate acceleration of growth, the

TABLE 3. THE INFLUENCE OF TIME AND DURATION OF BACITRACIN SUPPLEMENTATION OF GROWING-FATTENING RATIONS SELF-FED IN DRYLOT

Lot Number	2A	2B	4A	4B
Treatment [1]				
Weaning to 100 lb.	Basal	Basal	Basal+ bacitracin	Basal+ bacitracin
100 to 200 lb.	Basal	Basal+ bacitracin	Basal	Basal+ bacitracin
Number of pigs	4	4	4	4
Average initial weight, lb.				
Phase 1: weaning to 100 lb.	34.8	33.5	33.0	33.2
Phase 2: 100 to 200 lb.	99.8	100.8	100.2	101.8
Average final weight, lb.	201.8	198.8	203.0	202.0
Average daily gain, lb. and standard error:				
Weaning to 100 lb.	1.04±.04	1.05±.05	1.20±.04	1.21±.04
100 to 200 lb.	1.44±.07	1.46±.08	1.41±.07	1.56±.07
Weaning to 200 lb.	1.24±.05	1.26±.06	1.34±.07	1.39±.03*
Slaughter data:				
Av. cold dressed weight, lb.	159.2	156.9	156.5	160.6
Av. dressing percentage and standard error	79.0 ±.65	78.9 ±.56	77.1 ±.39[a]	79.5 ±.41
Av. backfat thickness, cm. and standard error	4.02±.33	3.84±.09	4.18±.18	4.32±.19

* Significant at 5% level over Lot 2A.

[a] Significantly lower dressing percentage than in Lots 2A, 2B and 4B.

[1] All bacitracin additions at 5 mg. per pound of ration furnished by pharmaceutical grade bacitracin. Basal ration included 0.125% vitamin B_{12} feed supplement.

gain being even slightly greater than for birds which had received the material from 1 day of age.

Deleting bacitracin from the ration of growing-fattening pigs in the test reported herein resulted in a cessation of the accelerated rate of gain observed from weaning to 100 pounds when the antibiotic was fed. This is in agreement with the data reported by Berg *et al.* However, the response to the addition of bacitracin to the basal ration was more marked with weanling pigs than with pigs weighing 100

pounds at the start of treatment. The initial advantage in gain due to early bacitracin supplementation is reflected in the higher, although not significant, over-all average daily gain by pigs in Lot 4A as compared with gains by pigs in Lot 2B.

No explanation is offered for significantly lower dressing percentage for hogs in Lot 4A which received bacitracin in phase 1 and the basal ration only during phase 2. No significant differences occurred in average thickness of backfat. It is interesting to note that the pigs receiving bacitracin throughout phase 1 and phase 2 (Lot 4B) averaged 0.3 cm. greater thickness of backfat than the basal group (Lot 2A). Perhaps with a greater number of pigs per treatment the difference in backfat thickness might prove to be significant. Vestal (1950) reported that hogs fed shelled corn and a protein supplement including an aureomycin fermentation product had approximately a 10 percent thicker layer of backfat at slaughter compared with control hogs of similar weights at time of slaughter.

Summary

The addition of 5 mg. aureomycin hydrochloride per pound of a 20 percent crude protein "corn-solvent soybean oil meal" ration fortified with minerals, vitamins A and D and riboflavin, pantothenic acid, niacin, choline and a vitamin B_{12} feed supplement fed to growing-fattening pigs in drylot from weaning to 100 pounds liveweight resulted in a 27 percent increase in rate of gain (highly significant). The addition of 5 mg. bacitracin to the same ration promoted a 16 percent increase in rate of gain (significant). The response from pharmaceutical grade bacitracin and from bacitracin feed supplement when each furnished 5 mg. bacitracin per pound of ration was essentially the same.

The deletion of the vitamin B_{12} feed supplement which furnished approximately 7.5 mcg. vitamin B_{12} per pound of ration from the above ration caused pigs to gain 15 percent slower, but the difference in gains was not statistically significant. The substitution of 3 percent condensed menhaden fish solubles for the vitamin B_{12} feed supplement in the basal ration plus an antibiotic (bacitracin) feed supplement did not significantly alter daily gains.

In a second phase of the investigation (100 lb. to 200 lb., drylot) pigs which had received no antibiotic supplementation from weaning to 100 pounds were subdivided into two groups; one group continued on the basal ration and the other group received 5 mg. bacitracin per pound of ration. Pigs which had previously received bacitracin from weaning to 100 pounds were subdivided in like manner, one group con-

tinuing to receive bacitracin and the other group being fed the basal ration. Under the conditions of this experiment best results were obtained when bacitracin was included in the ration for the entire period from weaning to 200 pounds liveweight. Pigs which received bacitracin in the ration throughout the entire feeding period gained significantly faster than pigs receiving no bacitracin supplementation throughout.

Literature Cited

Berg, L. R., G. E. Bearse, J. McGinnis and V. L. Miller. 1950. The effect of removing supplemental aureomycin from the ration on the subsequent growth of chicks. Arch. Biochem. 29:404.

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EFFECT OF VITAMIN B_{12} AND AUREOMYCIN CONCENTRATES ON THE GROWTH RATE OF UNTHRIFTY WEANLING PIGS

J. C. Blight, James X. King and N. R. Ellis

United States Department of Agriculture[1]

ONE of the significant factors limiting hog production is the loss due to the high incidence of unthrifty or cull pigs at weaning. Such a loss has been attributed to parasites, infectious diseases and faulty nutrition during the suckling period.

Since a great deal of interest has been shown in the results of feeding vitamin B_{12} and antibiotics to normal pigs, it seemed appropriate to study the effect of these growth factors on unthrifty slow growing pigs.

Experimental Procedure

After the requirements for other experiments had been satisfied, 42 pigs from the 1950 spring farrowing crop became available for this study. These pigs were from sows on pasture that had received a well balanced diet as indicated in table 1. The pigs were of various degrees of unthriftiness, however, and averaged but 18 pounds in weight at 56 days of age. After weaning, they were held for an additional 26 days before being placed on experiment. During the latter period they made an average daily gain of 0.3 pound.

At 82 days of age the pigs were distributed into three lots of 14 pigs each as near the same weight, age and litter characteristics as possible. They were placed in concrete floored pens and self-fed a basal diet containing 18 percent crude protein. The supplements added were as follows: lot 1, none; lot 2, vitamin B_{12} concentrate containing 3.5 mg. vitamin B_{12} per pound; lot 3, APF supplement containing 1.0 mg. vitamin B_{12} and 0.6 gm. aureomycin per pound.[2] The ingredients used in the diets are shown in table 2.

The animals were on experiment for 16 weeks and were weighed individually at weekly intervals during this period.

[1] Bureau of Animal Industry.

[2] The assays on the APF concentrate were supplied by the Food & Drug Administration of the Federal Security Agency, the figures on vitamin B_{12} content being supplied by the Division of Nutrition and those on aureomycin by the Division of Antibiotics.

TABLE 1. COMPOSITION OF SOW DIET [1]

Ingredients	Percent
Ground yellow corn	50.00
Coarsely grounds oats	20.00
Fish meal	3.75
Tankage (60% protein)	3.75
Alfalfa meal	15.00
Linseed oil meal	2.50
Soybean oil meal	3.75
Mineral mixture [2]	1.25

[1] Assay indicated the presence of 15 mcg. of vitamin B_{12} per pound of feed.
[2] Mineral mixture was composed of:

Ground limestone	28.0 percent
Steamed bonemeal	28.0 "
Iodized salt	24.0 "
Ferrous sulfate	1.6 "
Glauber's salts	18.4 "

Results and Discussion

The effects of the different feeding methods on subsequent gain and efficiency of feed utilization are shown in table 3. The arrangement is such as to permit a comparison between the performances of the 7 lightest and the 7 heaviest pigs in each lot. This division was made on the basis of initial weight.

TABLE 2. COMPOSITION OF EXPERIMENTAL DIETS FED TO THE THREE LOTS OF PIGS

Ingredients	Lot 1 [1]	Lot 2	Lot 3
	Percent	Percent	Percent
Ground yellow corn	70.0	69.7	69.7
Tankage (60% protein)	3.0	3.0	3.0
Fish meal	3.0	3.0	3.0
Soybean oil meal	10.5	10.5	10.5
Linseed oil meal	6.0	6.0	6.0
Alfalfa meal	6.0	6.0	6.0
Mineral mixture [2]	1.5	1.5	1.5
Vitamin B_{12} concentrate [3]	....	0.3	....
APF supplement [4]	....	....	0.3

[1] Contained 18% crude protein. Assay indicated the presence of 6.7 mcg. of vitamin B_{12} per pound.
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The addition of 5 mg. aureomycin hydrochloride per pound of a 20 percent crude protein "corn-solvent soybean oil meal" ration fortified with minerals, vitamins A and D and riboflavin, pantothenic acid, niacin, choline and a vitamin B_{12} feed supplement fed to growing-fattening pigs in drylot from weaning to 100 pounds liveweight resulted in a 27 percent increase in rate of gain (highly significant). The addition of 5 mg. bacitracin to the same ration promoted a 16 percent increase in rate of gain (significant). The response from pharmaceutical grade bacitracin and from bacitracin feed supplement when each furnished 5 mg. bacitracin per pound of ration was essentially the same.

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Since a great deal of interest has been shown in the results of feeding vitamin B_{12} and antibiotics to normal pigs, it seemed appropriate to study the effect of these growth factors on unthrifty slow growing pigs.

Experimental Procedure

After the requirements for other experiments had been satisfied, 42 pigs from the 1950 spring farrowing crop became available for this study. These pigs were from sows on pasture that had received a well balanced diet as indicated in table 1. The pigs were of various degrees of unthriftiness, however, and averaged but 18 pounds in weight at 56 days of age. After weaning, they were held for an additional 26 days before being placed on experiment. During the latter period they made an average daily gain of 0.3 pound.

At 82 days of age the pigs were distributed into three lots of 14 pigs each as near the same weight, age and litter characteristics as possible. They were placed in concrete floored pens and self-fed a basal diet containing 18 percent crude protein. The supplements added were as follows: lot 1, none; lot 2, vitamin B_{12} concentrate containing 3.5 mg. vitamin B_{12} per pound; lot 3, APF supplement containing 1.0 mg. vitamin B_{12} and 0.6 gm. aureomycin per pound.[2] The ingredients used in the diets are shown in table 2.

The animals were on experiment for 16 weeks and were weighed individually at weekly intervals during this period.

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[1] Assay indicated the presence of 15 mcg. of vitamin B_{12} per pound of feed.
[2] Mineral mixture was composed of:

Ground limestone	28.0 percent
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Glauber's salts	18.4 "

Results and Discussion

The effects of the different feeding methods on subsequent gain and efficiency of feed utilization are shown in table 3. The arrangement is such as to permit a comparison between the performances of the 7 lightest and the 7 heaviest pigs in each lot. This division was made on the basis of initial weight.

TABLE 2. COMPOSITION OF EXPERIMENTAL DIETS FED TO THE THREE LOTS OF PIGS

Ingredients	Lot 1 [1]	Lot 2	Lot 3
	Percent	Percent	Percent
Ground yellow corn	70.0	69.7	69.7
Tankage (60% protein)	3.0	3.0	3.0
Fish meal	3.0	3.0	3.0
Soybean oil meal	10.5	10.5	10.5
Linseed oil meal	6.0	6.0	6.0
Alfalfa meal	6.0	6.0	6.0
Mineral mixture [2]	1.5	1.5	1.5
Vitamin B_{12} concentrate [3]	....	0.3	....
APF supplement [4]	....	....	0.3

[1] Contained 18% crude protein. Assay indicated the presence of 6.7 mcg. of vitamin B_{12} per pound.
[2] Mineral mixture was composed of:

Ground limestone	57.7 percent
Steamed bonemeal	20.0 "
Iodized salt	20.0 "
Ferrous sulfate	2.0 "
Copper sulfate	0.1 "
Manganese sulfate	0.2 "

[3] Contained 3.5 mg. vitamin B_{12} per pound.
[4] Contained 1.0 mg. vitamin B_{12} and 0.6 gm. aureomycin per pound.

The average daily gain of the pigs in lot 2 receiving vitamin B_{12} supplement (21 mg. vitamin B_{12} per ton of feed) was not significantly more rapid than that of the pigs in lot 1 receiving the basal diet. Since the basal diet contained 13.3 mg. of vitamin B_{12} per ton, this level evidently is adequate for growth and the unthrifty condition can not be attributed to a deficiency of this vitamin in the diet. This is in conformity with the vitamin B_{12} requirement reported by Anderson and Hogan (1950).

TABLE 3. GROWTH RESPONSE AND FEED UTILIZATION OF UNTHRIFTY PIGS RECEIVING AUREOMYCIN AND VITAMIN B_{12} SUPPLEMENTS (16 WEEK PERIOD)

Lot No. and Feeding Methods	No. of Pigs	Av. Initial Weight	Av. Final Weight	Av. Gain in Weight	Av. Daily Gain	Feed Consumed per 100 lbs. Gain
		lbs.	lbs.	lbs.	lbs.	lbs.
Lot 1 (Basal Diet)						
Light	7	21.3	93.0	71.7	0.64	
Heavy	7	30.7	167.7	137.0	1.22	
Total	14	26.0	130.4	104.4	0.93	340.8
Lot 2 (Basal+Vitamin B_{12})						
Light	7	21.3	109.5	88.2	0.78	
Heavy	7	30.7	167.7	137.0	1.22	
Total	14	26.0	138.6	112.6	1.00	337.0
Lot 3 (Basal+Vitamin B_{12}+ Aureomycin)						
Light	7	21.7	149.0	127.3	1.14	
Heavy	7	30.7	174.4	143.7	1.28	
Total	14	26.2	161.7	135.5	1.21	341.4

The pigs in lot 3 receiving aureomycin (3.6 gm. per ton of feed) and vitamin B_{12} (6 mg. per ton of feed) as supplement to the basal diet made a significantly greater gain ($P<.05$) than the pigs in lots 1 and 2. The pigs in lot 3 were more uniform in size and more thrifty in appearance than the animals in the other two lots. Since the addition of vitamin B_{12} did not significantly affect the rate of gain over that of the pigs receiving the basal diet, the results indicate that aureomycin was responsible for the growth stimulation exhibited by lot 3.

The efficiency of feed utilization was almost identical in each of

Figure 1. Lightweight pigs of lot 1 receiving basal diet. (10th week of experiment)

the 3 lots (table 3), approximately 340 pounds of feed being required per 100 pounds of gain in body weight.

The animals in each lot were divided into sub-lots containing the 7 lightest and 7 heaviest pigs from the standpoint of initial weight. The results evaluated on this basis are shown in table 3. The differences between the light pigs and the heavy pigs in lots 1 and 2 can be attributed to a large degree to differences in initial weight. No differences in rate of gain attributable to differences in feeding were observed in the 3 sub-lots containing the heavy pigs. Although the light pigs in lot 2 gained at a somewhat faster rate than those in lot 1, this difference was not significant. The light pigs in lot 3 grew at a rate similar to that of the heavy pigs in the three lots, and significantly faster ($P<.02$) than comparable pigs in lots 1 and 2.

The light pigs in lot 3 (figure 3) were more uniform in size and more thrifty in appearance than those in lots 1 and 2 (figures 1 and 2).

Figure 2. Light weight pigs of lot 2 receiving basal diet plus vitamin B_{12} concentrate. (10th week of experiment)

A number of pigs in lots 1 and 2 were very unthrifty and had rough hair coats.

Summary

Weanling pigs of various degrees of unthriftiness were fed a well balanced diet supplemented with vitamin B_{12} and aureomycin concentrates.

The addition of vitamin B_{12} to the diet of slow-growing, unthrifty pigs did not significantly affect their gain.

Figure 3. Light weight pigs of lot 3 receiving basal diet plus APF supplement containing vitamin B_{12} and aureomycin. (10th week of experiment)

Similar pigs receiving aureomycin as supplement grew at a significantly faster rate and were more uniform in size and more thrifty in appearance.

Based on differences in initial weight, the response to aureomycin can be attributed primarily to its effect on the lighter more unthrifty pigs.

The factors contributing to the unthrifty condition of the pigs and the mode of action of the aureomycin were not apparent from this experiment.

Literature Cited

Anderson, G. C., and A. G. Hogan. 1950. Requirement of the pig for vitamin B_{12}. Jour. Nutr. 40:243.

COMPARISON OF GROWTH RESPONSES OF 2-DAY-OLD PIGS TO STREPTOMYCIN, AUREOMYCIN, AND CRUDE APF, ALONE AND IN COMBINATION WITH B_{12}[1]

B. E. Sheffy, R. H. Grummer, P. H. Phillips and G. Bohstedt

University of Wisconsin[2]

THE possibility of an improved performance of animals as a result of feeding bacteriostatic or bactericidal substances was first clearly demonstrated and reported by Moore *et al.* (1946). This observation with the subsequent discovery of B_{12} and antibiotics has opened a new field of nutritional research. Growth responses to antibiotics have since been reported for both chickens (Stockstad and Jukes, 1950) and swine (Jukes *et al.*, 1950) (Carpenter, 1950) (Luecke *et al.*, 1950). It has further been observed that maximal responses occur when the antibiotics are fed with proper amounts of B_{12} (Catron *et al.*, 1951).

All of the above references to work with swine concerned post-weanling pigs. Working with 2-day-old pigs Nesheim and Johnson (1950) used an alpha-protein "synthetic milk" ration to demonstrate a growth stimulus from streptomycin. Using the same ration, Wahlstrom *et al.* (1950) reported that aureomycin stimulated the growth of baby pigs but that no significant growth-promoting effect from added penicillin or sulfathalidine was observed.

Since "synthetic milks" can be prepared that are deficient in B_{12} they afford an excellent way to test the efficiency of various antibiotics with and without adequate dietary B_{12} in promoting growth of the baby pig.

This study was concerned with the growth-stimulating effect of streptomycin, aureomycin, and Lederle's crude APF.

Experimental

Thirty-two 2-day-old Hampshire pigs from five litters were allotted into eight groups (table 2). It was planned to use four 8-pig litters and to distribute each litter so as to have one pig from each litter in each lot. However, one pig from a fifth litter had to be used. The pigs were on experiment 26 days. Initial two-day weights were taken

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station. This work supported in part by Oscar Mayer & Co., Madison, Wis.

[2] Departments of Animal Husbandry and Biochemistry, Madison, Wis.

and thereafter they were weighed on the eighth, 14th, 21st, and 28th day. Weekly hemoglobin determinations were made on each animal. The pigs were fed *ad libitum* and were housed in individual screen-bottom cages.

TABLE 1. SEMI-SYNTHETIC MILK FORMULATION

Item	Gm. per Liter of Milk	Salts Mixture [2]	Grams
Casein [1]	50.0	NaCl	240.0
Cerelose	50.0	KH_2PO_4	520.0
Lard	60.0	$CaHPO_4$	680.0
Soya lecithin	5.0	$MgSO_4 \cdot 7H_2O$	145.0
Salts [2]	11.5	$CaCO_3$	155.0
$NaHCO_3$	2.0	Ca lactate	630.0
KOH	0.4	Ca citrate	455.0
Pectin	2.0	Fe citrate	40.0
Vitamins [3]		KI	2.0
	Per kilogram	$MnSO_4$	2.0
	dry matter	$ZnCl_2$	0.5
Supplementation:		$CuSO_4$	0.5
Vitamin B_{12}	56 γ	$CoSO_4$	0.5
Streptomycin	500 mg.		
Aureomycin	250 mg.		
Crude APF	10 gm.		

[1] Vitamin free, G.B.I.
[2] Modified salts IV, Phillips and Hart (1935).
[3] As reported by Johnson *et al.* (1947).

The basal ration was a typical "semisynthetic milk" using (G.B.I.)[1] vitamin-free casein as the source of protein (table 1). $NaHCO_3$, KOH, and a complete mineral mixture were added to six liters of warm water and briskly agitated with a Lightning stirrer.[2] The casein and cerelose were next added, and the mixture was allowed to mix for 20 minutes before the pectin, blended with 400 ml. of warm water in a Waring Blendor, was added to the mixture. The lard (one part lard, three parts water) which had previously been thoroughly homogenized with phospholipid by means of a multi-Flo valve homogenizer[3] at 2500 lb. pressure, was then added. The fat soluble vitamins were added at this time. This made approximately 10 liters of milk of 18 percent total solids. Microbiological assay for B_{12} with *Lactobacillus leichmannii* (Thompson *et al.*, 1950) consistently showed this ration to contain less than 1 γ of B_{12} activity per liter of milk. The

[1] General Biochemicals, Inc., Laboratory Park, Chagrin Falls, Ohio.
[2] "Lightnin" Model L Mixer, Mixing Equipment Co., Inc., Rochester, N. Y.
[3] C. P. Homogenizer (Multi-Flo Valve) Creamery Package Mfg. Co., Chicago, Ill.

TABLE 2. EFFECT OF VARIOUS ANTIBIOTICS AND B_{12}

Lot No.	Ration	Av. Initial Weight 2-day	Av. Final Weight 28-day	Av. Daily Gain
		lb.	lb.	lb.
I	Basal (low B_{12})	3.1	9.9	0.26
II	Basal+B_{12}	3.3	12.6	0.36*
III	Basal+streptomycin	3.2	11.1	0.30
IV	Basal+aureomycin	3.9	15.8	0.46**
V	Basal+B_{12}+streptomycin	3.0	13.6	0.41**
VI	Basal+B_{12}+aureomycin	3.6	15.9	0.47**
VII	Basal+B_{12}+strepto.+aureo.	3.0	15.1	0.47**
VIII	Basal+crude APF	2.8	9.7	0.27

* Significant at 5% level—L.S.D.=0.09 lb.
** Significant at 1% level—L.S.D.=0.12 lb.

water soluble vitamins, B_{12}, and antibiotics were added to the milk at the time of feeding.

During gestation the dams of the pigs were pastured on excellent ladino clover pasture and hand-fed one to two ears of yellow corn per day per sow during the last half of the gestation period. Starting a week before farrowing they were self-fed the following ration: 15 parts alfalfa, 15 parts of a 40 percent protein commercial hog supplement, 5 parts of corn, 15 parts of wheat, 48 parts of oats, and 1 part each of $CaCO_3$ and trace mineralized salt.

Results

A summary of the average performance of each of the eight groups of pigs appears in table 2. The average daily gains are shown in table 3

TABLE 3. AVERAGE WEEKLY RATES OF GAIN

Lot No.	Ration	2–8 Days	8–14 Days	14–21 Days	21–28 Days
		lb.	lb.	lb.	lb.
I	Basal (low B_{12})	0.12	0.28	0.27	0.31
II	Basal+B_{12}	0.23	0.22	0.37	0.57
III	Basal+streptomycin	0.28	0.35	0.29	0.30
IV	Basal+aureomycin	0.35	0.40	0.53	0.53
V	Basal+B_{12}+streptomycin	0.23	0.35	0.43	0.59
VI	Basal+B_{12}+aureomycin	0.30	0.33	0.53	0.69
VII	Basal+B_{12}+strepto.+aureo.	0.25	0.33	0.53	0.70
VIII	Basal+crude APF	0.12	0.08	0.39	0.43

on a weekly basis for each group. An analysis of variance (Snedecor, 1946) was made on the average daily gains and least significant differences were computed.

Antibiotic supplementation appeared to have little effect on palatability of the milk except in the crude APF lot where an adverse effect was noted during the first seven to ten days on experiment.

One of the pigs in the basal lot (1 γ B_{12} per liter of milk) died

TABLE 4. AVERAGE WEEKLY HEMOGLOBIN LEVELS
(gm./100 gm.)

Lot No.	Ration	1st Week	2nd Week	3rd Week	4th Week
I	Basal (low B_{12})	7.56	9.85	9.55	8.04
II	Basal+B_{12}	9.48	11.32	10.76	9.67
III	Basal+streptomycin	6.83	9.26	10.54	10.32
IV	Basal+aureomycin	8.66	10.67	8.73	11.82
V	Basal+B_{12}+streptomycin	7.83	8.10	8.97	9.68
VI	Basal+B_{12}+aureomycin	9.47	10.40	9.62	10.93
VII	Basal+B_{12}+strepto.+aureo.	6.69	8.81	8.28	8.99
VIII	Basal+crude APF	8.12	8.81	7.58	6.58

after 11 days on experiment. This pig and two other pigs in the basal lot exhibited symptoms of a B_{12} deficiency as described by Neumann *et al.* (1950). Hyper-irritability and posterior incoordination were both in evidence in these cases. The fourth member of this lot, the odd pig from the fifth litter, showed no deficiency symptoms and grew as well as the B_{12}-supplemented lot, thus indicating a possible difference in body stores between litters. There was no evidence of a B_{12} deficiency either by visible symptoms or growth differential in the aureomycin lot (IV). In the lot receiving streptomycin alone (III), however, there were visible symptoms of a B_{12} deficiency in two of the pigs beginning the third week. At this time there was also a leveling off of the daily rate of gain (table 4). Although there were no visible signs of a B_{12} deficiency in the aureomycin lot (IV), there was a leveling off of the daily rate of gain during the fourth week (table 4).

All treated groups except streptomycin alone (III) and crude APF (VIII) showed a significant or highly significant growth response over that of the basal (I) using the error mean squares of an over-all analysis of variance. Aureomycin alone gave stimulation equal to

aureomycin plus B_{12}; why the same did not hold true for streptomycin as compared to streptomycin plus B_{12} cannot readily be explained.

The growth responses as shown in table 3 demonstrate that the boost from antibiotics over B_{12} alone is most in evidence during the first two weeks of the experiment. The poor rate of gain during the first two weeks on experiment of the crude APF supplemented pigs is correlated with the period of low palatability and hence low feed intake.

Accurate feed consumption data could not be kept because of splashing and other forms of feed waste. However, a greater feed intake by the supplemented animals was quite evident. Thus, the growth differential was not necessarily due to any greater efficiency of utilization.

No consistent differences in the hemoglobin values were observed between the various lots (table 4). The blood hemoglobin level was found to vary considerably among the pigs regardless of age or supplementation.

Summary

A "semisynthetic milk" (low B_{12}) using vitamin-free casein as a source of protein was fed to 2-day-old pigs to demonstrate the growth-stimulating effects of B_{12}, streptomycin, aureomycin, and crude APF.

A dietary requirement for B_{12} for the baby pig was suggested.

Supplementation with aureomycin alone, aureomycin plus B_{12}, streptomycin plus B_{12}, and a combination of aureomycin, streptomycin, and B_{12} increased the daily rate of gain over that of the control ration.

No growth-promoting effect resulted from the supplementation of streptomycin alone or crude APF to the basal ration.

Better growth was observed when streptomycin and B_{12} were fed together than when streptomycin was fed alone. This was not apparent with aureomycin.

No consistent differences in the hemoglobin levels were apparent between the various lots.

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THE EFFECT OF VITAMIN B_{12}, AUREOMYCIN, STREPTOMYCIN, OR DRIED WHEY FACTOR SUPPLEMENTS ON THE GROWTH AND FATTENING OF WEANLING PIGS[1]

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THE essentiality of vitamin B_{12} in swine rations is well established. Early work of Neuman *et al.* (1949), closely followed by investigations of Anderson and Hogan (1950) and Nesheim *et al.* (1950), suggested a tentative requirement from 8 to 10 micrograms of vitamin B_{12} per lb. of dry matter for baby pigs reared on "synthetic" milk diets. More recently Vohs *et al.* (1951) indicated a practical vitamin B_{12} requirement of 5 micrograms per lb. of a corn-soybean meal ration fed to pigs from weaning to market weight in concrete pens.

The results reported by various investigators on the supplementary value of vitamin B_{12} in natural and synthetic rations for pigs are rather conflicting. Leucke *et al.* (1949), Willman and Noland (1949), Ferrin and Anderson (1949), Beeson and Bloss (1949), Dyer *et al.* (1950), and Vohs *et al.* (1951) have observed a stimulation in growth rate and generally a slight improvement in feed efficiency with additions of a vitamin B_{12} concentrate or crystalline B_{12} to practical plant protein rations for growing-fattening pigs. Anderson and Hogan (1949) and Lepley *et al.* (1950) reported a growth stimulation in pigs by feeding a crude B_{12} concentrate or dried whole aureomycin mash in meat protein rations. However, Colby and Ensminger (1950) showed no beneficial effect of injected or oral doses of vitamin B_{12} on the growth of pigs fed a purified ration. Similar results were shown by Cunha *et al.* (1949) and Burnside *et al.* (1950) when a mixture of B_{12} and B_{12b} or a B_{12} concentrate was fed orally or injected in pigs fed a corn-peanut meal ration during a 40-day feeding period. In this same Florida experiment, adding a B_{12}-aureomycin feeding supplement promoted faster pig growth. This suggested that apparently there was an essential factor or factors other than B_{12} or B_{12b} for optimum pig growth. Later work by

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 542, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

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Edwards *et al.* (1950) found that vitamin B_{12} is beneficial for pigs previously depleted on a corn-peanut meal ration. In 1949, the Florida workers reported that the B_{12}-aureomycin supplement improved the performance of plant protein rations equal to that of animal protein (fishmeal) rations for pigs. This was later confirmed by Vestal (1950). Beeson and Bloss (1949) presented evidence that there was an apparent difference in sex response to vitamin B_{12} supplementation of a practical plant protein ration for weanling pigs.

Vestal (1950) increased the rate of gain of growing-fattening pigs 14 percent on alfalfa pasture, 14 percent on oats and rape pasture, and 13 percent in dry lot by including 3 percent of a B_{12}-aureomycin concentrate in the soybean oil meal supplement. He also clearly demonstrated that the B_{12}-aureomycin concentrate improves growth and appetite of pigs fed an all-plant or mixed animal-plant protein ration in dry lot. Shortly afterwards these findings were confirmed by Lepley *et al.* (1950).

Dyer *et al.* (1950) reported a slight growth improvement with fortified dried whey additions to plant protein rations. This finding plus similar results reported on chicks by Hill *et al.* (1950) and Menge *et al.* (1950) have suggested that the so-called "dried whey factor" may be operating as a component of the APF complex.

Edwards et al. (1950), Jukes *et al.* (1950), and Leucke *et al.* (1950) showed in short-term experiments that streptomycin or aureomycin produces additional growth responses in pigs fed natural rations containing adequate vitamin B_{12}. Similar results have been shown by Stern and McGinnis (1950) in feeding antibiotics to rats reared on a semi-synthetic diet. These results on pigs and the laboratory rat, plus the chick studies of Stokstad and Jukes (1950), have suggested the multiple nature of the so-called "animal protein factor".

Because most of the experiments reviewed were of short duration, the present experiment was set up to study some of the various nutritional factors associated with the APF complex over the entire growing-fattening period of the pig.

The objectives of the present study with weanling pigs fed in concrete pens from weaning to market weight were:

(1) To compare the growth promoting value of two commercial APF supplements when fed to supply the same vitamin B_{12} activity in a basal all-plant protein ration fortified with the 3 B-vitamins for pigs in dry lot; (2) To determine if the so-called "dried whey factor" is one of the essential components of the "APF complex" for pigs; (3) To determine the effect of pure streptomycin in the absence or presence of

vitamin B_{12} in the basal pig ration; (4) To ascertain an effective level of streptomycin in the basal ration containing B_{12}; and (5) To study the effects of the various supplements on the feed requirement per unit gain.

Experimental

Pigs Used

Ten purebred Duroc weanling pigs were allotted into each of eight lots on the basis of weight, sex, and condition. Approximately equal numbers of barrows and gilts which averaged 36 lb. at the start were used in each lot. The pigs used were raised by sows fed nutritionally

TABLE 1. COMPOSITION OF BASAL RATION

Ingredients	Percent of Ration [1]
Ground yellow corn	62.60
Soybean meal, expeller	32.15
Alfalfa meal	5.00
Vitamin A and D oil	0.25
Total	100.00
Manganese (ppm.)	14.00
Total protein (percent)	21.80
Riboflavin (mg. per lb.)[2]	1.90
Niacin (mg. per lb.)[2]	24.49
Calcium pantothenate (mg. per lb.)[2]	9.90

[1] Mineral mixture of ground limestone, steamed bone meal, and iodized salt fed free choice.
[2] Includes the 0.8 mg. of crystalline riboflavin, 5.0 mg. crystalline niacin, and 4.5 mg. crystalline calcium pantothenate added per lb. of the natural ration plus the estimated amount of each vitamin in the natural ration.

adequate rations in dry lot and pasture during gestation and lactation which undoubtedly provided good vitamin stores in the pigs. The pigs were not depleted of vitamin B_{12} before starting the trial. The body weights and feed consumption of the pigs were taken at two-week intervals. The experimental pigs were self-fed continuously in concrete pens for 98 days. The original plan was to feed each lot of pigs until they averaged 210 lb. in weight. However, the experiment was closed out at the end of the 98-day feeding period because of an outbreak of bloody dysentery in the basal lot. No outbreak of bloody dysentery occurred in the pigs receiving antibiotics.

Basal Ration Fed

The composition of the all-plant protein basal ration is presented in table 1.

The basal ration was analyzed and found to contain 21.80 percent crude (total) protein and 14.0 ppm. of manganese. The protein level was reduced according to the needs of the pigs as they matured. A mineral mixture of 40 parts steamed bone meal, 40 parts ground limestone and 20 parts iodized salt was fed free choice. As shown in footnote of table 1, the three crystalline B-vitamins were added to the basal ration in amounts which fully met the vitamin allowances recommended by the National Research Council (1950) for weanling pigs.

Treatments

Various supplements of the animal protein factor complex were added in different combinations to the basal ration. The treatments that were employed are shown in table 2. Lederle's APF (B_{12}-aureomycin) supplement, a biofermentation product of *Streptomyces aureofaciens*, furnished approximately 2.0–2.5 mg. of vitamin B_{12} activity and 1.7 gm. of aureomycin per lb. Merck's APF (B_{12}) concentrate, a biofermentation product of *Streptomyces griseus*, contained a guaranteed potency of 12.5 mg. of vitamin B_{12} activity per lb. The dried whey fed in this experiment was the dried whey product without the added whey fermentation solubles (ribolac). The dried whey contained 15.0 percent protein, 59.5 percent lactose monohydrate, 12.1 percent ash, 4.4 percent lactic acid, and 3.6 percent moisture. The B_{12} content of the dried whey product ranged from .01 to .03 micrograms per gram. The streptomycin base was fed in the form of a calcium chloride complex.

In lots 2 and 3, the B_{12}-aureomycin and B_{12} supplements were added to supply about the same vitamin B_{12} activity, or about 12.5 mcg. of B_{12} per lb. of total ration which adequately meets the vitamin B_{12} requirement of the young pig. The pigs in lots 4 and 5 were fed a 2 percent level of the dried whey product (no ribolac) as Krider *et al.* (1949) have reported practically as good results with a 2 percent level as a 4 percent level. Lots 6 and 7 received 2.5 mg. and 15 mg. levels of streptomycin base per lb., respectively, in the basal ration supplemented with 0.10 percent Merck's B_{12} concentrate (similar to lot 3). Lot 8 received the basal ration supplemented with only 15 mg. of streptomycin base per lb.

Results and Discussion

The average daily gain, the average final weight after the 98-day feeding period, and the total feed requirement per 100-lb. gain for each treatment are summarized in table 2. Adding 0.5 percent B_{12}-aureomy-

cin (Lederle's) supplement to the basal ration (lot 2) significantly improved the growth rate of pigs from 1.44 to 1.76 lb., or about 22 percent, while supplementing the basal with 0.1 percent Merck's B_{12} concentrate (lot 3) increased the growth rate from 1.44 to 1.51 lb., or about 5 percent. The two supplements were added so as to furnish approximately 12.5 mcg. of B_{12} per lb. of total feed. The increase of

TABLE 2. THE GROWTH-PROMOTING VALUE OF VITAMIN B_{12}, AUREOMYCIN, STREPTOMYCIN OR DRIED WHEY IN PLANT PROTEIN RATIONS FOR WEANLING PIGS IN DRY LOT—SUMMER, 1950

	Av. Daily Gain [2]	Av. Final Weight (98 Days)	Total Feed per 100 lb. Gain
	lb.	lb.	lb.
Lot 1. Basal Ration	1.44	178	350
Lot 2.[1] Basal Ration+ 0.50% Lederle's APF (B_{12}+aureomycin)	1.76	209	340
Lot 3.[1] Basal Ration+ 0.10% Merck's APF (B_{12} only)	1.51	184	343
Lot 4. Basal Ration+ 2.0% dried whey product	1.30	163	333
Lot 5. Basal Ration+ 2.0% dried whey product+ 0.10% Merck's APF	1.50	183	365
Lot 6. Basal Ration+ 0.10% Merck's APF+ 2.5 mg. streptomycin base per lb.	1.54	187	340
Lot 7. Basal Ration+ 0.10% Merck's APF+ 15 mg. streptomycin base per lb.	1.69	202	338
Lot 8. Basal Ration+ 15 mg. streptomycin base per lb.	1.48	182	325

[1] APF supplements were added to supply approximately the same B_{12} activity. Lederle's APF contained 2.5 mg. of vitamin B_{12} and 1.7 gm. of aureomycin per lb.; Merck's APF contained 12.5 mcg. of vitamin B_{12} per lb.

[2] L.s.d., 5% level—0.17 lb.; L.s.d., 1% level—0.23 lb.

0.32 lb. in average daily gain in lot 2 (L.s.d., 5 percent—0.17 lb.) was significant; the increase in growth rate in lot 3 was not significant. The use of either vitamin-like supplement promoted a slight saving in feed per 100 lb. gain. This finding coincides with the report of Krider *et al.* (1949). These data suggest that factor or factors other than vitamin B_{12} are involved in promoting maximum pig performance in the feed lot. The stimulatory effect of the supplement fed in lot 2 is postulated to be due to the combination effect of B_{12} and the residual aureo-

mycin in Lederle's APF supplement. The above postulate is confirmed by more recent research at Purdue and other experiment stations on the stimulatory growth effect of pure aureomycin in pig and chick rations.

The feeding of 2 percent dried why product (no ribolac added) in the basal ration (lot 4) exerted a slight depressing effect on growth rate of pigs fed under these experimental conditions. However, 2 percent dried whey product appeared to have a slight favorable effect on feed utilization. The addition of 12.5 mcg. of vitamin B_{12} per lb. to the basal plus 2 percent dried whey failed to improve the pig performance above that of pigs fed the basal plus 12.5 mcg. vitamin B_{12} per lb. (lot 3). The lack of response from dried whey agrees fairly well with the recent findings of Stokstad and Jukes (1950) with chickens fed plant protein rations and of Terrill and Krider (1950) with pigs fed plant protein rations. The Illinois investigators failed to obtain a significant response with 5 percent dried whey product containing whey fermentation solubles in an all-vegetable protein ration for pigs. Earlier Krider *et al.* (1949), however, obtained a significant growth response with pigs from weaning to market weight by adding 2 or 4 percent fortified dried whey product to a corn-soybean meal ration containing 5 percent meat and bone scraps. In the same report, the Illinois workers showed a slight depression in growth rate of pigs from weaning to 75 lbs. with various supplemental levels of the dried whey product. Thus, the discrepancy between the dried whey responses reported herein and those reported by Krider and co-workers (1949) may be partly explained on the basis that the stimulatory response of the so-called "dried whey factor" is dependent upon factor(s) supplied by high quality meat scraps or similar meat proteins.

Supplementing a basal ration plus 12.5 mcg. of vitamin B_{12} per lb. with 15 mg. of pure streptomycin base per lb. of total ration (lot 7) significantly increased the growth rate over the basal ration plus only 15 mg. of pure streptomycin (lot 8). The feeding of pure streptomycin in lot 8 failed to promote a marked growth response over the basal ration (lot 1). These data strongly indicate that a combination of vitamin B_{12} and streptomycin is required for growth stimulation in pigs fed plant protein rations. The difference in growth responses in favor of lot 6 (15 mg. streptomycin level) over lot 7 (2.5 mg. streptomycin level) indicate that a 2.5 mg. level of streptomycin per lb. in a well fortified plant protein ration containing the added 3 B-vitamins and vitamin B_{12} is not adequate for a marked growth stimulation. Of all the treatments studied, the addition of pure streptomycin to the basal ration (or lot 8) had the most pronounced beneficial effect on feed utilization.

Light intermittent scouring occurred only in pigs in lot 4 which were fed the basal plus 2 percent dried whey product. All the other lots including the basal did not exhibit any noticeable diarrhea during the 98-day feeding period.

After being on the experiment for 14 weeks, the basal fed pigs (lot 1) became seriously infected with an enteric disease diagnosed as bloody dysentery. This automatically closed the trial for a comparison of all treatments to the basal ration. The other seven lots were carried on until the pigs averaged 200 lb. in weight. The differences in the growth rate of pigs at the end of this period were still in the same direction as at the close of the 98-day feeding period. During this interim period, the pigs on the seven different treatments did not become infected even though they were kept in the pens adjacent to the infected lot. The latter group of pigs was treated successfully with therapeutic doses of 1 gm. of crystalline aureomycin per pig in the feed the first day, and 0.5 gm. the second day after the outbreak. These interesting observations lead one to speculate that continuous oral feeding of aureomycin, streptomycin, or perhaps other well-known antibiotics, may exert a protective effect against certain intestinal infections in pigs, and thus promote growth indirectly.

The pigs fed the antibiotics and/or vitamin B_{12} had larger appetites and gained more uniformly within a lot during the experimental period. The pigs on the basal and dried whey treatments consumed less feed and were less uniform in growth response, compared with pigs on the other treatments.

Summary

The addition of 0.5 percent Lederle's B_{12}-aureomycin feeding supplement (supplying 12.5 mcg. vitamin B_{12} and 8.5 mg. of aureomycin per lb. of total ration) markedly stimulated the growth of pigs self-fed a corn-soybean meal-alfalfa meal ration fortified with cod liver oil, calcium pantothenate, riboflavin, niacin, and essential minerals, but exerted only a slight beneficial effect on the feed requirement per unit gain.

Supplementation of the basal ration with 0.1 percent Merck's B_{12} concentrate (supplying 12.5 mcg. vitamin B_{12} per lb. of total ration) improved pig growth and feed efficiency but not to the same extent as the B_{12}-aureomycin feeding supplement, thus showing an apparent beneficial effect of vitamin B_{12} and other factors, one of which is aureomycin in the supplement.

Two percent dried whey failed to increase the growth rate of the

basal-fed pigs. Even the combination of vitamin B_{12} and 2 percent dried whey (no ribolac) in the basal ration produced no better performance than vitamin B_{12} supplementation alone. This suggests that the "dried whey factor" is not essential for the optimum feed lot performance of pigs fed a practical plant protein ration.

The feeding level of 15 mg. of pure streptomycin base per lb. of total ration stimulated growth more than the 2.5 mg. level.

A combination of 12.5 mcg. vitamin B_{12} (0.1 percent Merck's B_{12} supplement) and 15 mg. of pure streptomycin per lb. of total ration improved growth rate and feed efficiency more than single additions of either factor.

These data suggest that vitamin B_{12} must be present in sufficient physiological amounts to produce maximum growth stimulation and improved feed efficiency with antibiotics fed in natural rations for pigs. Furthermore, the data emphasize that antibiotics exert their most favorable effect at definite optimum levels which must be established by experimentation.

Continuous oral feeding of the antibiotics protected the pigs against bloody dysentery.

Pigs fed the antibiotics and/or vitamin B_{12} grew more uniformly within a lot and consumed more feed, compared with the pigs fed the basal ration.

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TRACE MINERALS FOR GROWING-FATTENING SWINE FED IN DRYLOT[1, 2]

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THE experiment reported herein was designed to measure the supplementary value of a mixture of trace minerals including iron, copper, manganese, cobalt and zinc, when added to a basal ration composed of natural feedstuffs.

Grummer *et al.* (1950) has shown that pigs made faster daily gains when manganese was added to an all-plant protein basal ration at the rate of 40 ppm. Higher levels of manganese gave a response only slightly greater than the basal ration. Keith *et al.* (1942) found that 50 to 60 ppm. manganese prevented stiffness in swine fed a high ash diet containing considerable animal protein. However, Johnson's (1942) work showed that pigs made satisfactory growth on a synthetic diet containing less than 0.5 ppm. manganese.

Early work by Carroll and Mitchell (1928) indicated that there was no advantage in feeding copperas to pigs, yet, in more recent experiments, Anderson and Ferrin (1950) report a growth response from iron and copper fed either alone or in combination. Carpenter (1948) also got increased growth when pigs were fed additional copper.

Dinusson *et al.* (1950), in three different trials, found that cobalt increased daily gains when fed to swine in drylot. Robison (1950) also reports a growth response from added cobalt when pigs were fed an all-plant protein ration. Yet with rats, Houk *et al.* (1946) could not show a need for supplemental cobalt even though the cobalt content of the ration was less than 0.003 ppm.

Shrewsbury and Vestal (1943) reported that the addition of a combination of iron, copper, potassium, iodine, aluminum, zinc, magnesium and manganese to an all-plant protein ration failed to improve gains in growing-fattening pigs. However, Willman and Noland (1949) found that supplementary cobalt, copper, iron and manganese improved both growth and feed efficiency in swine. Later these workers (1950) tested

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cobalt, copper, and manganese separately and in combination. A combination of cobalt and copper gave the best results, whereas each of the elements added alone gave an intermediate result. Other combinations produced poorer results than any of the three elements alone.

It semed wise to investigate the need of additional trace minerals in our modern swine rations when considering the effects of soil erosion, continuous cropping, development of new crop varieties, changes in processing methods of feed ingredients and newer knowledge of the interrelationships between nutrients.

Experiment Procedure

The basal ration for this experiment was composed of 67.5 percent ground yellow corn, 20.0 percent blended expeller soybean oil meal, 5.0 percent blended meat and bone scraps, 0.5 percent APF (Lederle Lot 26 containing 2 mg. vitamin B_{12} and 2.3 gm. aureomycin per pound), 0.9 percent iodized calcium carbonate, 0.6 percent steamed bonemeal, and 0.5 percent salt. The following vitamins were added per pound of ration: 200 I.U. vitamin A, 400 I.U. vitamin D_2, 1.5 mg. thiamin HCl, 2.5 mg. riboflavin, 15 mg. niacin, 10 mg. calcium pantothenate, 1.5 mg. pyridoxine HCl, 500 mg. choline chloride, 0.5 mg. folic acid, and 1.5 mg. alpha-tocopherol acetate. Rations calculated to contain 18 percent crude protein were fed until the lots of pigs averaged 75 pounds. The protein was reduced to 15 percent from 75 to 150 pounds and to 12 percent from 150 to 200 pounds by an adjustment in the amounts of corn and soybean oil meal.

The mineral mixture was added to the basal ration at 3 levels, namely 0.05, 0.10 and 0.15 percent. When the trace mineral mixture was added at 0.05 percent it contributed 35.0 ppm. of iron, 29.5 ppm. of manganese, 2.4 ppm. of copper, 0.8 ppm. of cobalt, and 2.2 ppm. of zinc. All the minerals were added in the sulfate form.

Duroc pigs farrowed in the fall of 1949 and ranging in age from 60–73 days were allotted by litters into each of two replicates. These pigs were selected from three groups of sows receiving respectively, no supplemented trace minerals, 0.05 percent added trace mineral mixture and 0.10 percent added trace mineral mixture during gestation and lactation. Pigs were used from only those litters that included at least four rather uniform pigs. Six litters, two from each of the three gestation-lactation rations, were selected for each of the two replicates. Within each of the replicates each lot contained a litter mate from six litters. The pigs in replicate I had an average initial weight of 35.3 pounds and

were rated good whereas those in replicate II had an average initial weight of 26.7 pounds and were rated medium. The rations were assigned at random to the lots within each replicate.

The pigs were confined to concrete pens. Feed and water were offered *ad libitum*. Each pig was removed from the experiment as it reached approximately 200 pounds. Blood hemoglobins were determined at the beginning and end of the experiment. Chemical analyses of the rations were made for iron, manganese, copper, cobalt and zinc.

TABLE 1. SUMMARY OF RESULTS BY TRACE MINERAL LEVELS IN RATION

(Concrete Drylot-Winter 1949–50)

Lot[1]	Level of Trace Minerals Added	Av. Initial Weight	Av. Final Weight	Av. Daily Gain	Av. Daily Feed	Feed Per 100 lbs. Gain
				(pounds)		
Rep. I (Good Pigs)						
I	None	35.5	207.2	1.76	6.10	349
II	0.05%	35.7	214.2	1.80	6.26	349
III	0.10%	35.8	209.0	1.84	6.10	333
IV	0.15%	34.3	205.7	1.75	6.37	364
Rep. II (Medium Pigs)						
V	None	26.5	205.8	1.67	5.94	357
VI	0.05%	26.7	206.0	1.73	6.17	357
VII	0.10%	25.2	207.7	1.77	5.95	338
VIII	0.15%	28.3	204.5	1.74	5.78	333

[1] Six pigs per lot.

Results and Discussion

A summary of the results are given in table 1. Though the differences in average gains among rations were small, the trend was remarkably similar in each replicate. The lots of pigs fed the 0.05 percent level of trace elements gained faster than the basal. The pigs in both replicates fed the 0.10 percent level gained slightly more than those fed the 0.05 percent level; however, there was a decrease in gains of the pigs fed the 0.15 percent level. In replicate I, the lot of pigs fed the 0.15 percent level of trace minerals gained the same as the basal lot. In replicate II pigs fed the 0.15 percent level gained slightly less than those fed the 0.10 percent level of trace minerals.

The means of the average daily gains of both replicates for the pigs fed the basal, 0.05 percent, 0.10 percent, and 0.15 percent level of added mineral mixture were 1.72, 1.77, 1.80 and 1.74 pounds respectively.

Baringer's (1949) work showed a trend similar to the results observed in this experiment. Single lots of six pigs each in Baringer's experiment made the following average daily gains: 1.47, 1.60, 1.65 and 1.48 pounds respectively for the same trace mineral levels. The basal ration used by Baringer was similar to the one used in this experiment, except 2 percent fish solubles was fed instead of meat and bone scraps, and the basal ration was not supplemented with iodine.

An analysis of variance of the average daily gains, table 2, indicated that the differences among rations as measured by the quadratic regres-

TABLE 2. ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS

Source of Variation	Degrees of Freedom	Mean Square	F
Replicates	1	0.04570	
Mineral Levels	3	0.01629	4.76
Linear Regression	1	0.00894	
Quadratic Regression	1	0.03636	10.63*
Remainder	1	0.00357	
Reps. X Levels[1]	3	0.00342	
Remainder	40	0.01177	

* Significant at P=.05.
[1] Experimental error.

sion on the level of minerals were significant at the 5 percent level. Although the differences are small, the experimental error was extremely low. The regression equation was estimated to be $Y=1.72+1.64\ X -9.81\ X^2$, where Y is the average daily gain and X is the percentage of the mineral mixture added in the ration. This curve is at the maximum at X equals 0.084 percent of added minerals. Considerable caution should be exercised in the use of the equation since the variances of the coefficients and of the maximum are relatively large. This is because only four levels of trace minerals and only two lots of pigs per level were fed. The mean difference in average daily gains between the pigs fed the basal ration and those fed the 0.10 percent level of minerals was 0.088 pound, and the 95 percent confidence limits estimates of this difference are 0.012 and 0.164 pound.

The addition of trace minerals did not significantly influence the feed efficiency. Hemoglobin readings failed to reveal any significant differences attributable to ration treatments at the end of the experiment.

A summary of results of the daily gains of pigs by previous treatment, showed that pigs coming from sows and litters receiving no trace minerals during gestation and lactation made a daily gain of 1.70 pounds per day. Those pigs from sows receiving 0.05 percent level of trace minerals during the same period made a daily gain of 1.73 pounds per day. Pigs from sows fed 0.10 percent level of trace minerals during gestation-lactation made 1.82 pounds per day during the growing-fattening period. Although this experiment was designed to measure as efficiently as possible the effect of added quantities of trace minerals to the basal ration during the growing-fattening period, the possibility of "carry-over" effects from the addition of trace minerals to the ration for sows during gestation and lactation may be indicated.

TABLE 3. CHEMICAL ANALYSES OF TRACE ELEMENTS IN RATIONS[1]

Lot Numbers	I and V	II and VI	III and VII	IV and VIII
Level of Trace Minerals Added	None	0.05%	0.10%	0.15%
Element		(ppm)		
Manganese	15.62	49.55	90.70	116.10
Iron	358.00	296.00	336.00	343.00
Copper	5.85	8.25	10.85	14.05
Cobalt	0.04	1.00	1.72	2.52
Zinc	34.50	30.15	32.00	35.75

[1] Determinations were made by Calcium Carbonate Company, Quincy, Illinois.

In the chemical analyses of the rations (table 3), there was a gradual increase in the manganese, copper, and cobalt present, which agrees quite closely with the amounts added. The iron and zinc contents are variable and are high even in the basal ration. The amounts added were insignificant when compared to the amounts present in the basal ration, but whether the amounts in the natural ration are entirely available might be questionable.

Summary

A corn and soybean oil meal ration fortified with dehydrated alfalfa meal, meat and bone scraps, vitamins, APF supplement, iodized calcium carbonate, steamed bonemeal, and salt was fed to replicate lots of growing-fattening pigs. This ration was supplemented with a mixture of iron, copper, manganese, cobalt, and zinc at three different levels.

Though the differences were admittedly small, an analysis of variance showed that the experiment error was very low, and the average daily gains were significantly influenced (P=0.05) by the level of trace minerals fed. The regression of average daily gain on the level of minerals was curvilinear. The most rapid daily gains were at the 0.10 percent level of trace minerals. Trace minerals fed to sows during gestation and to sows and litters during lactation may have a subsequent influence on the growth response of the pigs from weaning to market. The chemical analyses of the rations would indicate that the improved performance from the addition of the different minerals was due to copper, manganese and/or cobalt. The differences found in feed efficiency and in hemoglobin readings were not statistically significant. The results of this experiment would indicate that swine rations composed of commonly used natural feedstuffs may be slightly deficient in one or more of the trace elements studied in this experiment if maximum growth is desired.

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TEMPERATURE ADAPTATION IN THE BABY PIG[1]

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DEATH losses in new-born pigs due to chilling are known to all swine producers in temperate climates. The American farmer loses well over a million pigs annually from this cause. While very commonplace, the actual changes taking place in the chilled pig and the part played by the heat control mechanism are not fully understood. The purpose of this paper is to present experimental work on the effects of chilling on baby pigs.

It has been known for some time that warm-blooded animals have a temperature regulating mechanism at the base of the brain in the hypothalamus. Temperature changes in the environment are reflected in the hypothalamus through the medium of nerve impulses (Barbour, 1912). Heavy losses resulting from chilling occur in baby pigs during the first few hours after birth, which might be expected from the work with other species. Kleiber and Winchester (1933) found that the normal body temperature in the chick is developed in about three weeks, which is comparable to rats (Brody, 1943, Jailer, 1950, and Wallach *et al.* 1948).

As to the cause of death in the pig from chilling, there has been little explanation. However, physiological reactions under various environmental conditions offer some explanation. Barbour (1921) found that when normal dogs were exposed to high temperatures the blood became diluted, but was concentrated when exposed to cold. However, when the hypothalamus was rendered inactive by sectioning the spinal cord at the sixth cervical vertebra, the blood solids remained constant in dogs exposed to hot and cold water baths (Barbour and Tolstoi, 1923).

It has also been demonstrated that hormones play a part in body temperature regulation. Burton (1939) found the thyroid to hypertrophy in animals exposed to cold, and Korenchevsky (1926) showed

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that after thyroidectomy, cooling causes a much more pronounced fall in body temperature than before.

It seems logical that the chilling problem in baby pigs is related to biological heat production. In this connection, Horvath *et al.* (1948) found that rats exposed to cold respond by greatly increased heat production, but the normal response was less in adrenalectomized rats. Cori (1931) states that the mechanism for maintaining a rather constant level of sugar in the blood is intimately connected with the action of insulin and epinephrine secretion.

Experimental Procedure

General

All pigs used in this experiment were from the Michigan State College swine herd. The majority of the pigs were Chester Whites and Durocs.

The warm room consisted of a farrowing pen 8 feet by 11 feet, insulated and equipped with a heater and thermostat to keep the temperature between 65 and 75 degrees F. The floor and wall were made of wood, and shavings were used for bedding. A continuous record of the temperature was made with a "Brown Recording Thermometer." For the data collected under "barn conditions," the pigs were farrowed in the central farrowing house at the Michigan State College swine barn. In severe weather, an electric heater kept the temperature above 50 degrees F.

A standard walk-in meat cooler with a temperature of 34 degrees F. was used for all of the chilling trials of short duration (two to three hours). For the chilling trials of longer duration, pigs were farrowed in a pen 8 feet by 11 feet, in a barn with no source of heat. During the time when data were recorded, a continuous record of environmental temperature was taken with a "Brown Recording Thermometer."

All body temperatures were taken rectally with a clinical thermometer recording in tenths of a degree Fahrenheit.

The Development of the Temperature Regulation Mechanism in the Baby Pig

Body temperatures were taken of pigs after birth, starting at one-half hour and then at six, 12, 24, 36, and 48 hours, and in some cases continuing up to ten days. Where a more complete comparison between pigs was desired, such as differences due to weight, temperatures were taken at ten minute intervals during the first hour after birth. Accurate birth weights were recorded for the purpose of comparing different sized pigs.

For a comparison of the rate at which body temperature regulation is developed under different environmental conditions, litters were farrowed in a warm room, 65°–75° F., and compared with pigs farrowed in a cold room, 25°–35° F.

The Effects of Chilling on Baby Pigs

Age and Birth Weight Studies. Two age groups were used in this part of the study: pigs from birth to four hours old, and another group 18 to 24 hours old. When pigs were chilled immediately after birth, the temperature of the sow was taken as the original pig temperature since they were found to be comparable. All chilling data were collected by placing the pigs in a standard meat cooler, with the exception of those chilled immediately after birth, in which case the pigs were farrowed in environments comparable to the cooler, or 30° to 34° F.

Each age group was divided into weight groups: those under 2 pounds and those weighing 2 pounds and over at birth.

In the observations of blood changes in chilled pigs, approximately 1.5 cc. blood samples were taken with needle and syringe from the anterior venous sinus immediately before chilling and immediately after. Blood hematocrits were run by the Wintrobe method (Kolmes, 1944), and blood sugars by the Folin modification of the Folin-WU method (Hoffman, 1941).

Results

Body Temperature Pattern Under Average Conditions

The average temperature responses of 25 pigs under barn conditions (environmental temperatures between 55° and 75° F.) show that the body temperature of a new-born pig drops by 3° to 12° F. during the first hour after birth, with the average being about 4° F., as seen in figure 1. The sharpest drop occurs during the first 20 minutes of life, and by the time the pig is an hour old, there is a gradual increase toward normal. The average temperature of 25 pigs observed was 98° F. at 20 minutes, 100.5° at 24 hours, and 102.3° at 48 hours.

Body Temperature Development Compared Under Warm and Cold Environments

The average body temperature drop of 16 pigs with an average birth weight of 2.5 pounds, born in the warm room, was 3 degrees during the first half hour after birth, the average at this age being 100.0° F. At one hour old, they showed a gradual increase to 100.2°. By the time the

pigs were 48 hours old the average body temperature was 102.0°, at 72 hours it was 102.2°, and at 96 hours it had reached 102.4° F., or almost back to normal (See figure 2).

The body temperature of the 19 pigs with an average birth weight of 2.4 pounds, born and raised in the cold, dropped lower during the first half hour of life, and the return to normal was at a slower rate than those born in the warm room, as can be seen in figure 2. The average

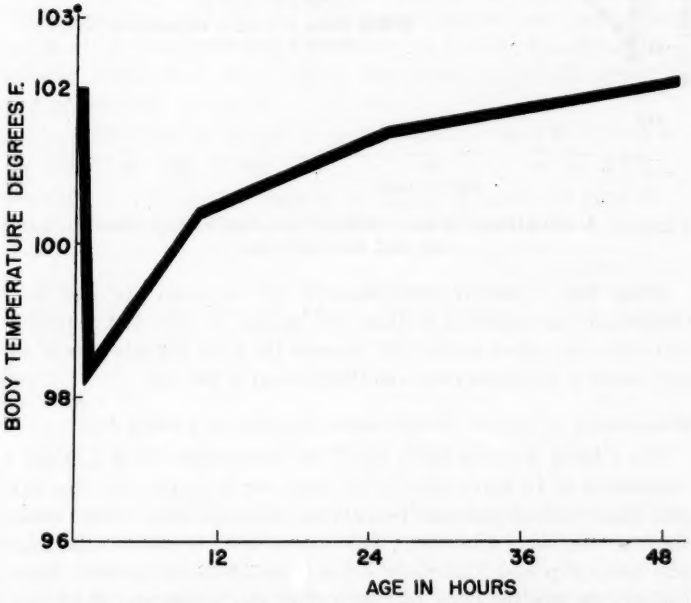

Figure 1. Relationship of age to body temperature in 25 pigs up to two-days-old. Environmental temperature 55 to 75°F.

drop for this group was 7.3 degrees at one-half hour, down to a temperature of 95.7° F. However, like those in the warm room, they showed a definite climb back toward normal. At one hour the average was 96.2°, in 48 hours 100.7° F., in 72 hours 101.4°, and in 96 hours 101.6° F.

At ten days old the pigs raised in the warm room showed an average body temperature of 102.7°, while those raised in the cold averaged 102.1° F.

During the first hour after birth no shivering or "hair raising" was observed in the pigs in the warm room, but was exhibited by those in the cold.

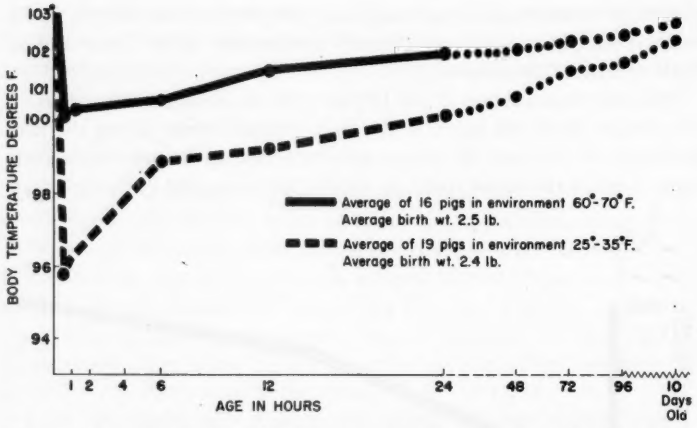

Figure 2. A comparison of body temperature drop in pigs raised in warm and cold environments.

There was a positive correlation of 0.77 between age and body temperature development in these two groups of pigs, and a positive correlation at a given age of 0.97 between the body temperatures of the pigs raised in the warm room and those raised in the cold.

Relationship of Size to Temperature Response in Chilled Pigs

Pigs Chilled Between Birth and Four Hours Old. Table 1 shows a comparison of 15 heavy pigs (2 lbs. and over at birth) and nine light pigs (under 2 lbs.) and their temperature responses when chilled during the first four hours after birth. The average birth weight for the larger pigs was 2.8 pounds, the range being from 2.3 to 3.5 pounds. Before chilling, the average body temperature of this group was 102.5° and after chilling 97.5° F. The average body temperature drop after chilling was 5.0°, the range being from 0.2° to 9.4° F.

TABLE 1. THE RELATIONSHIP OF BIRTH WEIGHT IN PIGS TO BODY TEMPERATURE DROP WHEN CHILLED[1]

Birth Weight	No. Pigs	Av. Birth Wt. Lbs.	Av. Body Tempt. Before Chilling	Av. Body Tempt. After Chilling 2 Hrs. @ 34°F.
			°F	°F
Over 2 lbs.	15	2.8	102.5	97.5
Under 2 lbs.	9	1.4	100.1	90.7

[1] Correlation of birth weight (x) to temperature after chilling (y). $r_{xy}=+76$.
Age range—Birth to 4 hours old.

The smaller pigs in this age group averaged 1.4 pounds, the range being from 1.1 to 1.7 pounds. Before chilling, the average body temperature of these small pigs was 100.1° and after chilling 90.7° F., or a drop of 9.4°, the drop ranging from 6.0° to 13.0° F.

There was a positive correlation of 0.76 between birth weight and temperature after chilling for these 24 pigs.

Pigs Chilled at 18 to 24 Hours Old. Table 2 shows a comparison of seven heavy and seven light pigs and their temperature response to chilling at about one day old. The larger pigs had an average birth weight of 2.2 pounds, ranging from 2.1 to 3.8 pounds. The average drop in body temperature after chilling three hours at 34° F., was 1.8°, ranging from 0.8° to 2.4° F.

The smaller pigs in this age group averaged 1.55 pounds at birth and

TABLE 2. THE RELATIONSHIP OF BIRTH WEIGHT IN PIGS TO BODY TEMPERATURE DROP WHEN CHILLED[1]

Birth Weight	No. Pigs	Av. Birth Wt. Lbs.	Av. Body Tempt. Before Chilling	Av. Body Tempt. After Chilling 3 Hrs. @ 34°F.
			°F	°F
Over 2 lbs.	7	2.2	101.7	99.9
Pigs under 2 lbs.	7	1.5	100.3	95.1

[1] Correlation of birth weight (x) to temperature after chilling (y). $r_{xy}=+.584$. Age range—18 to 24 hours old.

ranged from 1.1 to 1.9 pounds. Before chilling these pigs had an average body temperature of 100.3°, and after chilling 95.1° F. The average drop in body temperature was 5.2°; range 2.0° to 11.2° F.

There was a positive correlation of 0.58 between birth weight and temperature after chilling for these 14 pigs.

Blood Changes in Pigs Exposed to Chilling Temperatures

Blood Hematocrit (Cell Volume) Response. Blood samples taken before and after chilling at 34° F. and analyzed for volume of cells, showed a definite drop (blood dilution) in young pigs two to four days old (table 3a). Seven pigs in litter number 20 which were two days old at the time of the experiment, dropped from an average hematocrit of 34.0 percent before chilling to 26.8 percent afterwards, or an average drop of 7.2 percentage units. These pigs averaged 2.7 pounds at birth and showed an average body temperature drop during the chilling of 2.7° F. Three pigs in litter number 40 and five pigs in litter number 60,

TABLE 3. BLOOD RESPONSE IN PIGS EXPOSED TO CHILLING: CHANGES IN BLOOD HEMATOCRIT (CELL VOLUME) IN PIGS OF VARIOUS AGES

a. Pigs 2 to 4-Days-Old

Litter Number	No. Pigs	Av. Hematocrit—%		Body Temp.—°F.	
		Before Chilling	After Chilling[1]	Before Chilling	After Chilling[1]
20	7	34.0	26.8	102.1	94.4
40	3	33.7	25.0	101.8	101.6
60	5	33.0	28.6	102.0	101.7
	Mean	33.6	26.8*		

[1] Chilled 3 hours at 34° F.
* Significant drop in hematocrit.

which were three and four days old, respectively, also showed an average blood dilution when chilled. The average decrease in concentration in these litters was 8.7 and 4.4 percentage units, while the body temperature drop averaged 0.2° and 0.3° F., respectively.

As the pigs grew older, chilling caused almost no change in blood concentration. At ten-days-old, six pigs from litter 20 increased 0.6 percent in cell concentration and at 23 days, concentration decreased 0.8 percent. At 27 days old, the three pigs in litter number 40 also had less change in concentration, dropping an average of 1.5 percentage units. (tables 3b and 3c).

It can be seen from the tables that even two and three-week-old pigs exhibit some temperature drop when chilled. However, litter 20 was exposed to quite severe temperatures at ten days old; overnight at an average temperature of 25° F. This procedure was followed to get a comparison of the rate of the water-shifting response since all the other determinations were made on the basis of a three to four hour chilling

b. Pigs 10 to 12-Days-Old

Litter Number	No. Pigs	Av. Hematocrit—%		Body Temp.—°F.	
		Before Chilling	After Chilling[1]	Before Chilling	After Chilling[1]
20	6	30.2	30.8	102.8	101.8

[1] First sample taken while pigs were still in warm room. Second sample taken after sow and litter were in hog house overnight. (Av. temp. 25° F.).

c. Pigs 23 to 27-Days-Old

Litter Number	No. Pigs	Av. Hematocrit—%		Body Temp.—°F.	
		Before Chilling	After Chilling[1]	Before Chilling	After Chilling[1]
20	6	33.1	32.3	102.8	101.7
40	3	24.3	22.8	.....	.....
	Mean	28.7	27.6		

[1] Chilled 4 hours at 34° F.

period. Again at 23 days, litter 20 dropped an average of 1.1° in body temperature when chilled at 34° F. for four hours. Body temperatures were not taken of litter 40 during the latter chilling period.

Blood Sugar Response in Chilled Pigs

Pigs fasted 8 hours previous to chilling. Blood glucose changes in one-day-old pigs when chilled three hours at 34° F. after an eight-hour fast, are shown in table 4. The average of five pigs before chilling was 73.3

TABLE 4. BLOOD RESPONSE IN PIGS EXPOSED TO CHILLING:[1] CHANGES IN BLOOD SUGAR

Pig No.	Birth Weight Lbs.	Glucose mg/100 ml. Blood		°F. Body Temperature	
		Before Chilling	After Chilling (2)	Before Chilling	After Chilling (2)
12	2.8	71.1	105.7	101.0	100.8
14	3.4	69.0	71.1	101.0	100.8
16	3.0	80.0	97.5	101.0	100.0
17	2.4	69.0	108.6	102.0	100.4
18	2.6	77.7	115.0	101.2	98.8
11[3]	2.8	40.0	38.3	101.2	100.6
13[3]	3.0	71.1	75.5	101.0	98.8
15[3]	3.2	43.3	36.6	101.0	101.0
Av.. of	Control Pigs	51.5[3]	50.1[3]	101.1[3]	100.1[3]
Av. of	Chilled Pigs	73.3	99.6*	101.2	100.1

[1] One-day-old pigs were fasted 8 hours before beginning the experiment.
[2] Chilled 3 hours at 34°.
[3] Control pigs—left under brooder, away from sow.
* Highly significant increase in glucose.

mg. of glucose per 100 cc. blood. After being exposed to an environmental temperature of 34° F. for three hours, the glucose had increased to an average of 99.6 mg. per 100 cc., or an increase of 26.3 mg. The range before chilling was from 69.0 to 80.0 mg. per 100 cc., and after chilling from 71.1 to 115.0 mg. Three control pigs left under the brooder away from the sow during the three-hour period, averaged 51.5 mg. at the beginning and 50.1 mg. per 100 cc. at the end. The body

TABLE 5. BLOOD RESPONSE IN PIGS EXPOSED TO CHILLING:[1] CHANGES IN BLOOD SUGAR

Pig No.	Birth Weight Lbs.	Glucose mg/100 ml. Blood		°F. Body Temperature	
		Before Chilling	After Chilling (2)	Before Chilling	After Chilling (2)
15–2	2.7	92.5	97.5	101.8	100.4
15–3	2.0	32.1	55.5	101.4	98.2
15–5	1.2	25.0	48.3	100.6	90.0
15–10	1.5	73.33	25.00	98.4	90.0
15–11	1.4	33.6	35.0	101.0	90.0
15–1[3]	2.7	87.5	78.9	101.4	102.4
15–9[3]	1.6	53.6	50.0	101.6	101.6
Av. of Control Pigs		70.60[3]	64.40[3]	101.5[3]	102.0[3]
Av. of Chilled Pigs		51.30	52.30	100.6	93.7
Av. of Chilled Pigs Excluding No. 15–10		45.80	59.10*		

[1] One-day-old pigs on 5 hour fast before start of experiment.
[2] Chilled 2 hours at 34° F.
[3] Control pigs—left under brooder, away from sow.
* Significant increase in glucose.

temperatures of the control pigs did not change while the chilled pigs dropped an average of 1.1° F.

Pigs fasted 5 hours previous to chilling. Pigs in this group also exhibited an increase in blood sugar when chilled, as seen in table 5. While the average for the chilled pigs increased only from 51.3 mg. to 52.3 mg. per 100 cc. blood, it can be seen from the table that pig number 15–10 exhibited a drastic drop instead of an increase. Excluding this pig, the average for the chilled group increased 13.3 mg. per 100 cc.

of blood. In this group, the two control pigs dropped slightly in blood sugar, from 70.6 mg. to 64.4 mg. per 100 cc. blood. The body temperature of the chilled pigs dropped from an average of 100.6° to 93.7° F., while the controls increased slightly, from 101.5° to 102.0° F.

Reference to table 5 reveals the wide variation in the size of these pigs. The four pigs under two pounds not only exhibited a much greater drop in body temperature when chilled, but showed a more varied blood sugar response. For example, pig number 15–11, weight 1.4 pounds, showed very little change in glucose, while pig number 15–10, weight 1.5

TABLE 6. BLOOD RESPONSE IN PIGS EXPOSED TO CHILLING:[1] CHANGES IN BLOOD SUGAR

Pig No.	Birth Weight Lbs.	Glucose mg/100 ml. Blood		°F. Body Temperature	
		Before Chilling	After Chilling (2)	Before Chilling	After Chilling (2)
12–1	2.8	105.7	128.3	102.0	99.3
12–2	3.5	97.5	160.0	101.0	98.0
12–4	2.0	85.0	125.0	101.6	100.4
12–6	3.1	66.0	115.0	102.6	99.8
12–8	2.6	108.6	155.0	101.6	100.2
12–3[3]	2.8	95.0	118.3	101.6	101.8
12–5[3]	3.0	100.0	115.0	102.0	102.0
Av. of Control Pigs		97.5[3]	116.6[3]	101.8[3]	101.7[3]
Av. of Chilled Pigs		92.5	136.6*	101.8	99.5

[1] One-day-old pigs fasted 3 hours before start of experiment.
[2] Chilled 3 hours at 34° F.
[3] Control pigs—left under brooder, away from sow.
* Highly significant increase in glucose.

pounds, dropped from 73.3 mg. to 25.0 mg. per 100 cc. Both of these pigs dropped to 90.0° in body temperature. It should be pointed out here that at the end of two hours at 34.0° F., the three small pigs, numbers 15–11, 15–5, and 15–10, all weighing 1.5 pounds or less had gone into a slight coma and were lying prone on the floor, too weak to rise. After being thoroughly warmed under the brooder in the farrowing pen, they were up again and nursing. (See figure 3).

Pigs fasted 3 hours previous to chilling. Pigs fasted only three hours before the start of the experiment exhibited the same general trends in blood glucose response as the two other groups, table 6. Before chilling,

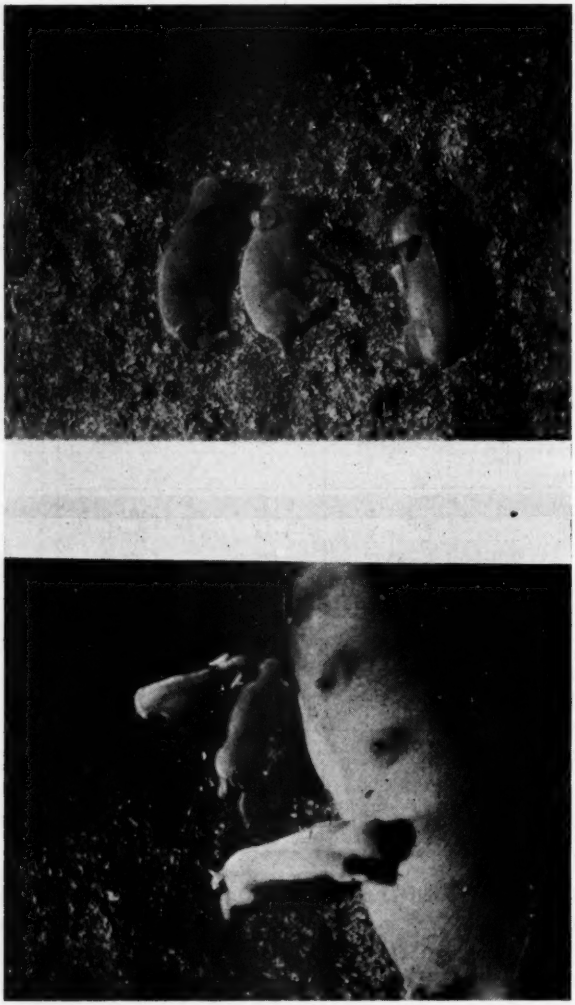

Figure 3. Above. Coma developed in one-day-old pigs resulting from chilling. All pigs weighed under 1.5 pounds at birth. After two hours at 34°F. they were lying in the above position, too weak to rise. As a part of the blood sugar trials, these pigs were fasted five hours prior to chilling, thus showing the low energy reserves for very small pigs.

Below. The same three pigs after warming three hours under the pig brooder (80°F.).

five pigs in this group averaged 92.5 mg., and after chilling three hours at 34° F., had increased to 136.5 mg. glucose per 100 cc. blood, or an increase of 44.0 mg. The control pigs increased 19.0 mg., which is considerably more than the control pigs on an 8 and 5 hour fast, both of which dropped slightly. The chilled pigs suffered a slight drop in body temperatures, averaging from 101.8° to 99.5° F. The controls decreased 0.1° F. Again, as can be seen from the table, there was a wide variation among the pigs and their blood sugar response when chilled. Pig number 12–2 increased from 97.5 mg. to 160.0 mg., or an increase of 62.5 mg. per 100 cc. blood, while number 12–1 increased only 22.6 mg.

Discussion

Cannon (1929) has shown that homeothermic mechanisms are not required by the developing mammal before birth. At birth and thereafter, however, survival becomes increasingly contingent upon the exercise of these mechanisms, and so poikilothermic embryos develop into homeothermic adults.

The sudden drop of body temperature after birth in the baby pig indicates a lack of development of the temperature regulating mechanism. The temperature development curves in figures 1 and 2 seem to illustrate graphically Cannon's theory. It can be seen from figures 1 and 2 that at two days old pigs born in warm environments had practically reached the temperatures of their dams, or 102.5°, which is reported by Dukes (1943) to be normal body temperature for swine.

It is evident that the amount of drop and length of time required to gain full control of body temperature is directly related to the environmental temperature.

The fact that the pigs in the cold room regained normal body temperature more slowly than those in the warm room would imply that the mechanism for heat production is underdeveloped at this age. Barbour (1941) found this heat production mechanism to be present at birth in some species, but absent in others. However, the increases in blood glucose found in one-day-old chilled pigs indicate a mechanism for increased heat production.

Other factors related to temperature regulation are shivering and the "raising" of the hair, and are under the control of the hypothalamus (Ranson, 1940). It would seem that this particular mechanism is quite well developed in the baby pig, since at about one hour old it was observed that the pigs born in the cold were shivering and that the hair was standing erect.

It can be seen from tables 1 and 2 that small pigs (under 2 pounds) at birth have a much sharper body temperature drop when chilled than pigs over 2 pounds. It can also be seen that very young pigs in both weight groups drop a little lower when chilled than pigs about one day old. These results would be expected from the work of Brody (1945). He states that "The basal heat production per unit of body weight in homeotherms decreased rapidly with increasing weight." Also from the law of Newton is derived the fact that the heat loss from a body is proportional to its surface area. These two statements translated into terms of this experiment seem to explain the greater temperature drop in the light pigs. This would be expected, as the lighter pigs must produce more heat per unit of body weight to maintain normal temperature. The lighter pig has proportionately more surface area from which to radiate heat than a larger pig. It has also been demonstrated in these experiments that one-day-old pigs have a better developed temperature regulating mechanism than pigs at birth.

These data indicate that many of the smaller pigs are unable to withstand freezing temperatures for more than a few hours.

Baby pigs are obviously very sensitive to cold environments, this depending greatly on the size and age after birth. There are, no doubt, factors other than body temperature involved in reactions of young pigs at low temperatures. Milking ability of the sow, time elapsed between birth and nursing, and fasting (see figure 3) are related to the pig's ability to withstand low temperatures and should be studied further.

Age of the pigs at the time of chilling seems to have an important influence on the hematocrit change. From table 3, it can be seen that the young pigs (up to four days old) showed a definite drop in cell concentration while the ten day and three-week-old pigs remained about the same. This means that the young pigs used in the experiment actually had an increase in the water content of the blood, thereby causing a decrease in cell concentration. In the older pigs, there was apparently no shifting of water in either direction; the blood cell concentration remaining almost unchanged.

Blood dilution (decrease in cell volume) shown in the young pigs is the reverse of that in animals with a normally functioning temperature regulating mechanism, according to Barbour (1923). He found that dogs respond regularly to a moderately high environmental temperature by blood dilution and to a cold environmental temperature by blood concentration.

Pigs about two to three weeks old showed very little hematocrit change in either direction (tables 3b and 3c). This would seem to

indicate further the lack of development of the temperature regulating mechanism in very young pigs; gradually becoming adapted to low environmental temperatures at two to three weeks old. At just what age the pig shows the normal blood concentration reaction when cooled, was not determined in this study since no pigs over three weeks of age were used in the blood determinations. It should be pointed out that Howie and co-workers (1948) observed lower than normal hemoglobin values in eight-week-old pigs raised in cold environments.

Increase in blood sugar has been known for some time (Freund and Strassman, 1912) to be a phenomen occuring when warm-blooded animals are exposed to cold.

It should be pointed out here that even with an increase in blood sugar, most of the pigs used in the experiment showed a drop in body temperature; the amount of drop depending on the size of the pig. The three small pigs (table 5) whose body temperature dropped to 90.0° F. when chilled, had a varied response in blood sugar; one increasing, one remaining about the same, and the other decreasing. The reason for a drop of 48.3 mg. of glucose per 100 cc. blood in pig 15–10 instead of an increase, cannot be easily explained. However, Rodbard (1947) found a blood sugar drop in chicks when they were cooled sufficiently to cause a drop in body temperature. It is also assumed that the glycogen reserves are lower in a small pig and would be depleted more rapidly.

From these data it can be seen that pigs fasted eight hours before the start of the experiment showed a lower blood sugar level before chilling and increased less than those fasted only three hours. This is in agreement with the observations of Hanawalt and Samson (1947) who found the blood sugar levels in pigs to be proportional to the length of the fasting period.

It was not possible in these experiments to study the mechanism causing an increase in blood sugar when pigs were chilled. However, Hartman and Brownell (1949) state that cold is one of the most effective means of stimulating both the medulla and cortex of the adrenal gland, indicating increased adrenal hormone secretion. It has also been shown by Cannon *et al.* (1924), Cori (1931), and others, that epinephrine injected into animals causes an increase in blood sugar, arising primarily from the glycogen in the liver.

The blood sugar rise shown in these pigs is apparently a defense mechanism of the body against cold. Horvath *et al.* (1938) showed that normal rats respond to cold by greatly increased heat production, the caloric output per 24 hours increasing from an average of 895 to about 2500 calories per square meter. He also found that the increase in heat

production on exposure to cold is less in the unilaterally adrenalectomized than in the normal rat. That the thyroid is also important in this respect was shown by Marine and Lenhart (1920) who found that epinephrine does not exert its normal calorigenic effect in the absence of the thyroid.

Summary

Body temperature development of baby pigs was studied under various conditions of environmental temperature. The effects of chilling on body temperature and blood changes in pigs ranging in age from birth to three weeks old were studied.

1. The body temperature regulating mechanism in the new-born pig is not fully developed. There was a body temperature droy of 3° to 13° F. in baby pigs during the first 30 minutes after birth, the amount of drop being related to the size of the pig and the environmental temperature. The initial drop was followed by a gradual return toward normal, which in environments of 60°–75° F. was reached in about two days, and in environments approaching freezing temperatures was reached in about ten days.

2. Pigs 24 hours old withstood a temperature of 34° F. with less drop in body temperature than pigs under 4 hours old.

3. There was a significant correlation between the weight of a pig and its ability to adapt itself to its environment. Small pigs in a fasting state passed into a coma sooner when chilled than pigs of comparable size having access to sow's milk.

4. Chilling of two-day-old pigs caused the blood hematocrit to decrease, which is a reversed reaction for the normally functioning temperature regulating mechanism.

5. There was an increase in blood sugar when one-day-old pigs were chilled at 34° F. Pigs fasted eight hours before chilling showed less glucose increase than those fasted three and five hours.

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INBRED VERSUS NON-INBRED BOARS USED IN TWO SIRE HERDS ON WISCONSIN FARMS [1]

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MOST of the testing of the combinability of inbred lines of swine has been in linecrosses within experiment station herds until just recently when topcrossing of inbreds on non-inbred farm stock was begun. Hazel, Musson and Lush (1948), reporting a study conducted on Iowa farms, found Landrace topcrosses superior to the outbreds on the same farm by twelve pounds in 154-day weight and by 3.5 percent in viability from birth to 154 days. They found the topcrosses from inbred Poland China boars to be one pound heavier than the outbreds and 2 percent better in viability. Durham, Chapman and Grummer (1949) in a preliminary report of similar work on Wisconsin farms, showed significantly larger numbers of pigs farrowed by gilts sired by Beltsville Landrace-Poland China inbred boars than by daughters of outbred boars used on the same farms.

The work reported here includes the results of all four years of testing progeny produced by inbred boars mated to unrelated outbred gilts in farm herds. The purpose of the experiment was to determine if there was any superiority in the economic characteristics of topcross pigs sired by inbred boars (representing different inbred lines) as compared to pigs sired by non-inbred boars. It was hoped that this work not only might throw light on the general combinability of samples from several lines when used in topcrosses, but might also provide evidence of any differences in combinability in topcrossing lines of divergent origin.

Materials and Methods

The variables studied were number of pigs farrowed per litter, number weaned, number at 5 months of age, and percentage viability from birth

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to 5 months of age in litters sired by inbred and outbred boars. The weights at 56 and 154 days of age and the gain between these ages for individual pigs sired by these same boars were also studied as were the productivity and ovulation rates of some of their daughters. Progeny from inbred boars will be denoted as topcrosses and progeny of non-inbred boars will be denoted as non-topcrosses.

Inbreeding work with swine was begun at the Wisconsin station in

TABLE 1. INBREEDING COEFFICIENTS OF INBRED BOARS, NUMBERS OF INBRED BOARS, NUMBERS OF FARMS AND THE NUMBERS OF TOPCROSS AND NON-TOPCROSS LITTERS AND PIGS BY LINE

Line[1]	Coef. of Inbreeding	No. of Inbred Boars	No. of Farms	No. of Topcross Litters	No. of Non-topcross Litters	No. of Topcross Pigs	No. of Non-topcross Pigs
LPC	.30	6	10	78	80	518	532
LCW	.41	3	3	22	17	133	101
Land.	.27	1	2	10	13	66	83
PC	.22	6	6	66	117	374	707
AK	.16	4	4	19	18	132	115
PM	.20	7	8	56	56	351	390
MA	.31	7	7	42	36	272	235
CY	.25	4	4	21	29	122	188
Total	.27	38	44	314	366	1968	2351

[1] LPC—Landrace-Poland China (76% Landrace, 24% Poland China)—Beltsville
LCW—Landrace-Chester White (80% CW, 20% Landrace)—Beltsville
Land.—Landrace—Iowa
PC—Poland China (several lines pooled—Scoutmaster, Alliance, Blackbird and inbred linecrosses of these and other lines)—Iowa
AK—Alfalfa King (Chester White)—Wisconsin
PM—Purdue's Moderator (Chester White)—Wisconsin
MA—Model A (Chester White)—Wisconsin
CY—Chester-Yorkshire (54% Chester White, 46% Yorkshire)—Wisconsin

1941. The need for farm cooperation in testing the inbred lines was one of the factors which prompted the formation of the Wisconsin Swine Selection Cooperative in 1945. Such a cooperative was a potential source of contact with the farmers who might cooperate in the testing work.

Inbred boars from the Wisconsin and Iowa Experiment Stations and the U.S.D.A. Experiment Station at Beltsville were first placed on farms in 1946. Table 1 gives the lines and breeds tested, the average inbreeding coefficients of the boars, the number of inbred boars, the number of farms and the numbers of litters and pigs sired by the inbred and outbred boars in the various groups. The Iowa Poland China (PC) group were made up of three inbred linecross boars and one boar from each of three lines—Scoutmaster, Alliance and Blackbird. Over-all analysis of the data was carried out with each of the three PC lines

classified separately and also with them and the inbred linecrosses pooled. The results of these two analyses did not differ. The pooled PC data only are given in the tables.

Where possible, the comparisons between topcrosses and non-topcrosses were subdivided into those in which all litters were within the same breeds and those in which all litters were crossbred. The distribution of these comparisons is given in table 2.

TABLE 2. NUMBERS OF LITTERS AND PIGS IN THE TOPCROSS AND NON-TOPCROSS COMPARISONS WITHIN THE SAME BREEDS AND WITHIN CROSSBRED GROUPS

Line	Kind of Litters	No. of Topcross Litters	No. of Non-topcross Litters	No. of Topcross Pigs	No. of Non-topcross Pigs
PM	Straightbred	33	32	190	214
	Crossbred	23	24	161	176
MA	Straightbred	15	13	86	73
	Crossbred	27	23	186	162
AK	Straightbred	10	11	63	65
	Crossbred	9	7	69	50

The boars were placed on farms where the farmer had agreed to breed at least five gilts to the inbred boar and at least five to a non-inbred boar of his own choosing. The farmers were asked to divide the gilts at random so as to avoid any conscious selective advantage of the gilts bred to either boar. In some cases the boars were alternated as the gilts came into heat—the first gilt to show heat going to one boar, the second to the other, etc. On some farms the gilts were placed in two lots or pastures with each boar being assigned to a group of gilts. The mates of each boar were marked at or before breeding time, so that the sire of the litter could be readily identified when the pigs were farrowed.

At birth, each pig was ear notched for individual identification and a record card was filled in for each litter. The pigs were weighed at approximately 56 and 154 days. Weaning weights were adjusted to a standard age of 56 days by the method of Whatley and Quaife (1937) and "five-month weights" to a standard age of 154 days by the method of Lush and Kincaid (1943). Gains were then calculated by subtracting the 56-day weight from the 154-day weight for each pig. Viability was

taken as the percentage of pigs farrowed which was alive at 154 days. These percentages were transformed to angles equal to the arc sine times the square root of the percentage for analysis (Snedecor, 1946).

Each farmer was asked to select for his breeding herd some of the gilts sired by the inbred boar and some of those sired by the outbred boar. An index was calculated for each pig, and a list of the "top index"

TABLE 3. NUMBERS OF LITTERS FARROWED AND WEANED IN EACH LINE REPRESENTED IN THE TOPCROSS AND NON-TOPCROSS GILT COMPARISONS

Line	Number of Litters Farrowed		Number of Litters Weaned [1]	
	Topcross	Non-topcross	Topcross	Non-topcross
LPC	60	56	55	53
LCW	21	13	21	13
Land.	8	8	8	8
PC	35	98	35	98
AK	24	13	18	8
PM	24	18	24	18
MA	15	18	15	18
CY	13	14	13	14
Total	200	238	189	230

[1] Farrowing records were obtained on one farm of an LPC comparison where weaning records could not be obtained due to an incidence of cholera before weaning time, and on one farm of an AK comparison where weaning information was not available for inclusion in this study.

gilts sired by each boar on a particular farm was sent to the farmer to aid him in selecting the superior females in each group. In most cases, all topcross and non-topcross gilts on a farm were bred to one boar. If the farmer was using two boars, each boar was bred to approximately equal numbers of topcross and non-topcross gilts. In no cases were the boars related to their mates.

Wherever possible, records were obtained on the performance of these gilts in the next farrowing season. Table 3 gives the number of topcross and non-topcross gilt comparisons classified by the line of the topcross gilt's sire.

Data were obtained on ovulation rates of topcross females sired by Landrace-Poland China inbred boars and of non-topcrosses from each of three farms. Ovulation rate was estimated from the number of corpora lutea found in the ovaries of those gilts which had only one crop of corpora lutea.

An analysis of variance of the differences between topcrosses and non-topcrosses, based on herd means, was made over all lines. The inter-

action between mating system (topcross versus non-topcross)[4] and line was also tested for significance. The error term used for the tests of significance of the over-all mating system × line interaction was the mean square for interaction between mating system and farm within lines. The over-all mating system differences were tested against the same error term unless the mating system × line difference was found to be significant, in which case it was used as the error term.

Analysis of the data for 154-day weights followed by examination of the probable sources of differences between the lines in mating system effects ($P \cong 0.06$) led to the pooling of the LPC, Land., AK and CY groups (all of which showed results in favor of the topcross) and then comparing them to the other lines (LCW, PC, PM and MA) in which the topcrosses were inferior to the non-topcrosses. This particular pooling of lines was then maintained for all other variables.

The technique used for isolating the single degree of freedom for this comparison is one suggested by Dr. H. W. Norton in personal communication. This technique is consistent with the method given by Snedecor (1946), when the numbers of observations per group are equal. Recognition of the *a posteriori* reasoning in the choice of these groupings of lines can be made by modification of the probability values associated with the "F" or "t" value, or by using a method given by Cochran (1941).

Analysis of the variance within individual lines was done by the method of weighted squares of means (Snedecor, 1946). This analysis of the data made it possible to test the significance of the interaction of mating system and farm within each line and provided an error term to test the significance of the over-all difference between mating systems within a line.

Samples of topcross pigs sired by boars of the LPC, CY and Wisconsin Yorkshire lines and non-topcross pigs from the same three farms were brought to the University farm and fed out individually. The experiment was begun with three topcross and three non-topcross pigs from each farm. In the course of the experiment two pigs died, leaving two non-topcrosses for the LPC comparison and two non-topcrosses for the Yorkshire comparison. These pigs were started on feed at 72 days of age, and self-fed to a final weight of 210 pounds. They were weighed weekly and individual feed consumption was obtained for each week on feed. When they reached 210 pounds they were taken off feed for 20 hours and then slaughtered at the University Meats Laboratory. The

[4] The fact that the differences between topcrosses and non-topcrosses include the differences in transmitting ability between the particular boars used (inbred and non-inbred) and the additive genetic differences between the groups represented as well as any non-additive genetic line effects is implied in this use of "mating system."

carcasses were chilled for 24 hours and the right side of each was then used for study. Length of body was measured from the aitchbone to the first rib as the carcass hung on the hook. Average fat back thickness was calculated from measurements at the first rib, seventh rib, last rib and last lumbar vertebra. Differences between the topcrosses and non-topcrosses within each group were tested for significance by the least significant difference method.

Results

Size and Viability of Topcross and Non-topcross Litters

Table 4 shows the average number farrowed, number at 56 days and number at 154 days, by lines, for litters sired by inbred boars, and for those sired by non-inbred boars. The average percentage viability from birth to 154 days for each line is also given in this table.

An over-all analysis of the mean differences was made and gave no indication of a general difference between topcross and non-topcross litters in any of these variables. The lack of significant interaction between line and mating system provides little or no evidence that the lines are performing differently in comparison with their controls, as far as size of litter and survivability are concerned.

Within-line analyses give little or no indication of interaction between farm and mating system in any of the lines for numbers farrowed, weaned, and alive at 5 months and percent viability.

A further subdivision of the data for some of the lines into crossbred and straightbred herds according to the breeding of the litters is given in table 5. The only differences which were highly significant were those for the straightbred PM litters, in which the numbers weaned and at 154 days are smaller for the topcrosses than the non-topcrosses. There was no indication of this in the PM crossbred group. A suggestion of superior viability from farrowing to 154 days of age was found for the topcrosses in the MA straightbred and AK crossbred groups.

Rate of Gain and Weight for Age

Table 6 gives the means and mean differences between the mating systems by line for 56-day weight, rate of gain from 56 to 154 days, and 154-day weight of the individual pigs. The over-all means and mean differences between topcrosses and non-topcrosses are given at the bottom of the table.

The analysis of these over-all mean differences did not show any general superiority of the topcrosses over the non-topcrosses. A significant interaction between mating system and line suggested differential

TABLE 4. MEANS AND MEAN DIFFERENCES BETWEEN MATING SYSTEMS FOR NUMBERS OF PIGS FARROWED AND AT 56 AND 154 DAYS OF AGE AND PERCENTAGE VIABILITY BY LINES

	Number Farrowed			Number Weaned			Number at 154 Days			Viability (%)		
Line	TC [1]	NTC [2]	TC-NTC	TC	NTC	TC-NTC	TC	NTC	TC-NTC	TC	NTC	TC-NTC
LPC	8.91	8.98	—.07	6.81	7.02	—.21	6.59	6.72	—.13	75.1	74.7	.4
LCW	7.77	7.47	.30	5.70	6.47	—.77	5.67	6.30	—.63	76.1	83.4	—7.3
Land.	9.50	9.25	.25	7.40	7.40	.00	6.60	6.35	.25	70.4	70.7	—.3
PC	8.31	8.20	.11	6.53	6.50	.03	6.23	6.25	—.02	76.9	77.5	—.6
AK	9.38	8.58	.80	7.15	6.23	.92	7.03	6.10	.93	78.7	71.6	7.1
PM	8.64	9.20	—.56	6.84	7.48	—.64	6.44	7.04	—.60	77.0	77.0	.0
MA	8.43	9.27	—.84	6.59	6.66	—.07	6.20	6.41	—.21	75.6	69.0	6.6
CY	8.25	8.68	—.43	6.28	6.95	—.67	6.03	6.78	—.75	76.6	79.4	—2.8
Average	8.65	8.70	—.05	6.66	6.84	—.18	6.35	6.49	—.16	75.8	75.4	.4

[1] Topcross
[2] Non-topcross

TABLE 5. MEANS AND MEAN DIFFERENCES BETWEEN MATING SYSTEM FOR NUMBERS OF PIGS FARROWED AND AT 56 AND 154 DAYS OF AGE, AND PERCENTAGE VIABILITY BY LINES, WITHIN CROSSBRED AND STRAIGHTBRED GROUPS

		Number Farrowed			Number Weaned			Number at 154 Days			Viability (%)		
Line	Kind of Litters	TC	NTC	TC-NTC	TC	NTC	TC-NTC	TC	NTC	TC-NTC	TC	NTC	TC-NTC
PM	Straightbred	8.18	9.05	−.87	6.05	7.30	−1.25**	5.75	6.78	−1.03**	74.9	75.9	−1.0
	Crossbred	9.10	9.35	−.25	7.65	7.65	.00	7.13	7.30	−.17	79.2	78.2	1.0
MA	Straightbred	7.40	8.83	−1.43	5.93	6.03	−.10	5.73	5.83	−.10	80.3	67.1	13.2*
	Crossbred	9.20	9.60	−.40	7.08	7.13	−.05	6.55	6.85	−.30	72.1	70.4	1.7
AK	Straightbred	8.40	7.90	.50	6.65	6.10	.55	6.50	5.85	.65	77.4	77.2	.2
	Crossbred	10.35	9.25	1.10	7.65	6.35	1.30	7.55	6.35	1.20	80.0	66.0	14.0*

* $P<.05$
** $P<.01$

performance among the lines for gain from weaning to 154 days ($P \cong 0.04$) and 154-day weight ($P \cong 0.06$). On the basis of these results the lines were put into two groups, with four lines—LPC, Land., AK, CY—which had a higher mean than the topcrosses, in one group, and four lines—LCW, PC, PM, MA—which had a lower mean than the non-topcrosses, in the other group. The mean square for the single degree of freedom for the difference in gain and 154-day weight between these two groups was found to be highly significant after allowance was made, in the test of significance, for the *a posteriori* selection of the lines for each group.

Within-line differences between topcross and non-topcross pigs were found to be highly significant for gain and 154-day weight in the AK

TABLE 6. MEANS AND MEAN DIFFERENCES BETWEEN THE MATING SYSTEMS FOR 56 DAY WEIGHT, RATE OF GAIN FROM 56 TO 154 DAYS, AND 154 DAY WEIGHT OF THE INDIVIDUAL PIGS BY LINE

Line	Weaning weight (lbs.)			Gain (lbs.)			154-day weight (lbs.)		
	TC	NTC	TC-NTC	TC	NTC	TC-NTC	TC	NTC	TC-NTC
LPC	29.0	26.6	2.4	108.4	102.1	6.3	137.4	129.1	8.3
LCW	27.3	25.4	1.9**	81.9	85.4	−3.5	109.2	110.8	−1.6
Land.	23.0	24.2	−1.2	79.3	70.9	8.4*	102.3	95.0	7.3
PC	28.7	29.0	−.3	102.3	103.2	−0.9	131.0	132.5	−1.5
AK	28.4	27.1	1.3*	127.5	118.6	8.9**	155.9	145.6	10.3**
PM	23.7	24.0	−.3	96.6	104.4	−7.8	120.2	128.4	−8.2
MA	27.1	25.9	1.2	102.1	104.1	−2.0	129.3	129.9	−0.6
CY	30.4	28.3	2.1	113.7	106.2	7.5	144.0	134.5	9.5
Over-all Average	27.2	26.3	0.9	101.5	99.4	2.1	128.7	125.7	3.0

* $P < .05$
** $P < .01$

group, and in weaning weight for the LCW group. There was no evidence of interaction between mating system and farm for these characters in these lines.

The LPC and CY topcross pigs were heavier at weaning, gained faster, and were heavier at 154 days than the non-topcrosses. The PM topcrosses were slower gainers and lighter at 154 days. These differences were "significant" when the error term used to test them was the within-mating system and farm variation, but not when tested against the interaction between mating system and farm, which itself was significant. Thus the differences were not consistent from farm to farm and the actual over-all difference should not be taken as grounds for inference to all sets of conditions.

The means and mean differences for the herds classified into straightbred or crossbred litter groups are given in table 7. Of the three lines so

TABLE 7. WEANING WEIGHT, GAIN AND 154 DAY WEIGHT FOR TOPCROSS AND NON-TOPCROSS PIGS FOR HERDS WHICH IT WAS POSSIBLE TO CLASSIFY AS STRAIGHTBRED OR CROSSBRED

		Weaning Weight (lbs.)			Gain (lbs.)			154-day Weight (lbs.)		
Line	Kind of Litters	TC	NTC	TC-NTC	TC	NTC	TC-NTC	TC	NTC	TC-NTC
PM	Straightbred	24.5	23.3	1.2	96.4	103.8	—7.4	121.0	127.1	—6.1
	Crossbred	22.9	24.8	—1.9	96.7	104.9	—8.2	119.5	129.7	—10.2
MA	Straightbred	27.8	26.7	1.1	97.7	101.2	—3.5	125.5	127.9	—2.4
	Crossbred	26.6	25.3	1.3	105.5	106.3	—.8	132.1	131.5	.6
AK	Straightbred	30.6	28.5	2.1	131.8	118.2	13.6**	162.3	146.7	15.6**
	Crossbred	26.2	25.6	.6	123.3	119.0	4.3	149.5	144.6	4.9

** $P < .01$

classified the AK topcrosses in straightbred herds were significantly faster in gain from weaning to 154 days and heavier at 154 days than the topcrosses ($P<.01$). None of the other mating system differences was significant.

Efficiency of Feed Utilization and Carcass Characteristics of Topcrosses and Non-topcrosses

Data on feed consumed per pound of gain on the pigs from certain lines which were fed out individually are shown in table 8. Averages for four segments of the growth curve are given as well as average daily consumption from 72 days to 210 pounds and the percentage shrink when off feed for 20 hours before being slaughtered.

None of the differences for the Yorkshire, LPC and CY topcross-non-topcross comparisons was highly significant. There was, however, significantly more feed consumed per pound of gain from 72 days to 154 days and from 72 days to 210 pounds in the CY topcrosses compared to their non-topcross controls. The topcrosses shrank significantly less than the non-topcrosses when taken off feed for 20 hours, but in terms of pounds of feed per pound of carcass weight, the topcrosses were still less efficient than the non-topcrosses.

The data for carcass characteristics are given in table 9. None of the differences between topcrosses and non-topcrosses was significant for any of the carcass variables studied.

The numbers of animals representing each group in the efficiency and carcass studies are so small that major differences only could have been detected.

Productivity of Topcross and Non-topcross Gilts

Table 10 gives gilt productivity in terms of number of pigs farrowed, number weaned, and the weaning weight of the litters of topcross and non-topcross gilts by lines, with the mean differences for each line and for the over-all comparison. The gilts listed in this table are the daughters (retained for breeding from the previous farrow) of inbred and non-inbred boars.

Over-all analysis of the mean differences showed that the topcross gilts farrowed and weaned more pigs ($P<.01$) and their litters were heavier at weaning ($P<.01$) than the non-topcross gilt litters. The usual tendency for larger numbers of pigs per litter to be associated with lighter individual pig weights is not found here in that the topcrosses excel the non-topcrosses both in number of pigs weaned and in individual

TABLE 8. FEED CONSUMED PER POUND OF GAIN FOR FOUR SEGMENTS OF THE GROWTH PERIOD, AVERAGE DAILY CONSUMPTION FROM 72 DAYS TO 210 POUNDS, AND PERCENTAGE SHRINK WHEN OFF FEED FOR 20 HOURS BEFORE BEING SLAUGHTERED

Item	Yorkshire Topcross	Non-top-cross	TC-NTC	LPC Topcross	Non-top-cross	TC-NTC	CY Topcross	Non-top-cross	TC-NTC
Feed consumed per pound gain from 72 days to 112 days (lbs.)	3.56	3.11	.45	3.09	3.25	—.16	4.34	3.03	1.31
Feed consumed per pound gain from 72 days to 154 days (lbs.)	3.67	3.52	.15	3.48	3.80	—.32	4.34	3.37	.97*
Feed consumed per pound gain from 112 days to 154 days (lbs.)	3.75	3.80	—.05	3.70	4.18	—.48	4.53	3.57	.96
Feed consumed per pound gain from 72 days to 210 pounds (lbs.)	3.96	3.90	.06	3.85	4.12	—.27	4.91	3.69	1.22*
Average daily feed consumption from 72 days to 210 pounds (lbs.)	5.88	5.71	.17	6.12	5.25	.87	6.28	5.84	.44
Percentage shrink	5.11	4.52	.59	6.32	4.52	1.80	3.80	6.17	—2.37*

* $P < .05$

TABLE 9. DATA ON SOME CARCASS CHARACTERISTICS OF TOPCROSS AND NON-TOPCROSS PIGS FED INDIVIDUALLY FROM 72 DAYS TO 210 POUNDS

Characteristic	Yorkshire Topcross	Non-top-cross	TC-NTC	LPC Topcross	Non-top-cross	TC-NTC	CY Topcross	Non-top-cross	TC-NTC
Back fat thickness (ins.)	1.67	1.60	.07	1.39	1.35	.04	1.82	1.51	.31
Body length (ins.)	29.93	29.05	.88	30.10	30.10	.00	28.40	28.33	.07
Percent fat in carcass	16.56	16.83	—.27	14.52	13.63	.89	18.99	15.14	3.85
Percent fat in live weight	11.92	12.80	—.88	10.52	10.48	.04	14.28	11.36	2.92
Percent of five primal cuts in carcass	66.74	63.58	3.16	68.48	67.06	1.42	66.13	67.70	—1.57
Percent of five primal cuts in body weight	48.64	48.30	.34	49.74	51.54	—1.80	49.68	50.74	—1.06
Dressing percent	72.43	73.25	—.82	73.82	75.32	—1.50	75.84	75.30	.54

pig weights. Approximately three-fourths of the differences between topcross and non-topcross gilt litters in litter weaning weight arose from differences in number weaned and about one-fourth from differences in weight of individual pigs.

The mean squares for the interaction of line and mating system in number farrowed and weaned, though not significant, were suggestive of differential performance among the lines. The mean square for the single degree of freedom between the same two groupings of lines used in the analysis of rate of gain showed that the LPC, Land., AK, and CY group was better ($P<.01$) in number farrowed and number weaned than was the LCW, PC, PM and MA group. Differences between topcross and non-topcross gilts for the former group of four lines were 2.04

TABLE 10. NUMBER FARROWED, NUMBER WEANED, AND WEANING WEIGHTS OF THE LITTERS OF TOPCROSS AND NON-TOPCROSS GILTS BY LINES

	Number farrowed			Number weaned			Weaning weight of litter		
Line	TC	NTC	TC-NTC	TC	NTC	TC-NTC	TC	NTC	TC-NTC
LPC	10.47	8.24	2.23*	8.30	6.55	1.75**	252.7	186.7	66.0
LCW	9.73	9.15	.58	7.32	6.79	.53	196.0	166.4	29.6
Land.	12.50	9.50	3.00*	10.50	8.10	2.40*	261.1	232.5	28.6
PC	8.60	8.28	.32	6.13	6.22	—.09	165.8	146.3	19.5
AK	10.30	9.30	1.00	8.70	7.65	1.05	237.8	202.6	35.2
PM	9.90	10.07	—.17	7.40	6.30	1.10	192.4	130.9	61.5
MA	9.30	8.87	.43	7.23	6.78	.45	180.4	168.0	12.4
CY	8.00	6.07	1.93*	5.50	4.10	1.40	139.9	98.7	41.2
Over-all Average	9.85	8.69	1.16**	7.64	6.56	1.08**	203.6	166.4	37.2**

* $P<.05$
** $P<.01$

more pigs farrowed and 1.65 more pigs weaned for the topcross gilts. The differences for the latter group of four lines were .29 more pigs farrowed and .50 more pigs weaned for the topcross gilts.

Analysis of variance for individual line comparisons indicated that the topcross gilts sired by the LPC and Landrace boars farrowed and weaned significantly more pigs (approximately 30 percent) than the non-topcross gilts on the same farm. Topcross gilts sired by a CY boar farrowed significantly more pigs than did the non-topcross gilts on the same farm and weaned about 30 percent more pigs. AK topcross gilts farrowed more pigs and AK and PM topcrosses weaned about one pig more than did the non-topcrosses, but the differences were not significant. It should be noted that, even though none of the other individual line differences for the litters of topcross versus non-topcross gilts were significant, all but two of the differences were in favor

of the topcross litters and these two differences were the smallest differences observed.

Ovulation Rate of Topcross and Non-topcross Gilts

Data were obtained on ovulation rate of LPC topcross gilts from three herds (table 11). Egg counts, estimated from the number of corpora lutea present in gilts which had ovulated only once, gave a difference of 1.63 eggs in favor of the topcross gilts. This difference was not significant with these small numbers, but it was consistent from herd to herd.

TABLE 11. OVULATION RATE OF LPC TOPCROSS GILTS FROM THREE HERDS

Item	Topcross	Non-topcross	Difference
Number of gilts	10	10	....
Number of eggs ovulated	10.63	9.00	1.63

Discussion

The analyses of the over-all mean differences for numbers farrowed and raised and for percentage viability to 154 days of age between topcross and non-topcross litters gave no indication of mating system effects. The absence of interaction between mating system and line indicates that there is no reflection in these characteristics of topcrosses from different lines performing differently relative to their controls.

The results of the analyses of variance of mean differences between mating systems showed no significant over-all effect of mating system on rate of gain and 154-day weight but did suggest that there is differential performance, with respect to mating system, between lines.

The analyses of the mean differences between topcross and non-topcross gilts for the components of gilt productivity gave significant over-all values in favor of the topcross gilts and suggested a differential effect of mating system with respect to lines. From these results it would appear that high productivity of gilts is more generally expressed as a heterotic effect than is rate of gain. In none of the measures of gain and productivity does the intraline performance of the inbred ancestry indicate that the superiority of the topcross progeny could have arisen from an additive genetic contribution of the inbred sires.

The significant differences between the two groups of lines—LPC,

Land., AK and CY compared with LCW, PC, PM and MA—with respect to mating system, for rate of gain, 154 day weight, and number farrowed and weaned in the topcross-non-topcross gilt comparisons give evidence of differential performance among the lines in favor of the LPC, Land., AK and CY over the other four lines combined. It is felt that these results point to a rather general heterotic effect for this combination of lines in which rapid gain and high gilt productivity occurred in the same group of individuals.

In the cases in which it was possible to compare the differences between mating systems within straightbred and crossbred herds there was little evidence of differential effects of mating system with kind of litter.

The data on feed used per pound of gain do not indicate any general or specific advantage for the topcrosses. This is in accord with the work of Dickerson *et al.* (1946) in which faster gaining linecrosses were little, if any, more efficient than the parent lines. Their studies indicated that the linecrosses apparently had greater daily maintenance needs which tended to cancel out the favorable effects of a shorter maintenance period. Likewise, the carcass data do not show superiority of the topcrosses compared with non-topcrosses from the same farm. The pigs were fed the same ration under similar conditions from weaning to slaughter and hence had equivalent opportunity to express any genetic tendencies toward different fat-lean ratios. The small numbers, however, in the efficiency and carcass studies would allow major effects only to be established.

When each line is considered in the light of the over-all analysis and the individual line-by-line analyses that were applied to the topcrosses and the non-topcross controls for each of the characters, the following tendencies emerge:

1. The AK line boars appear to be superior to the outbred control boars in siring pigs with higher rate of gain and weight at 56 and 154 days. There is also a suggestion of superior general combinability for high productivity in topcross gilts from this line.
2. The LPC line results suggest better performance for rate of gain but this performance is not consistent from farm to farm. There were two out of ten farms in which the topcross did not exceed the non-topcross in weights at 56 and 154 days and gain between these ages. Productivity records on topcross and non-topcross gilts show that the boars tested from this line have

sired daughters which were, on the average, markedly higher in numbers farrowed and weaned and litter weaning weight than the daughters of the control outbred boars.

3. Results for the CY line are similar in all characters to those for the LPC line.
4. The Landrace line was represented by one boar with progeny produced on two farms. As far as these comparisons go, good combinability was indicated for both rate of gain and topcross gilt productivity.
5. The LCW comparisons show little evidence of differences between topcrosses and non-topcrosses in the estimates of gain and topcross gilt productivity.
6. The results from the MA comparisons and the PM comparisons were as non-committal as those from the LCW group. The interactions between mating system and farm, resulting from rather large positive differences between topcrosses and non-topcrosses on some farms and large negative ones on others point to the possibility of variation in combinability of each of these lines or differential response to a different environment.
7. There were no highly significant differences between the topcross and non-topcross groups for any character in the PC lines.

These specific line tendencies may be looked on as possible trends which require confirmation from additional data before they can be accepted as clearly characterizing these groups.

One way that the noted heterosis may be acting is in an earlier physiological maturity in topcrosses than in non-topcrosses. There were indications in these results that the lines which had superior growth rate were the ones which tended to give superior production in their topcross gilts. This suggests that faster development may be occurring in the topcrosses. The data obtained on ovulation rates indicate that the topcrosses may be ovulating more eggs at the first heat period.

Several workers—Lush and Molln (1942), Blunn and Baker (1949), Hetzer *et al.* (1940), Russell and Hutton (1938), and Stewart (1945)—have shown that number farrowed increases with age at farrowing. Other workers—Warnick *et al.* (1950), Wiggins *et al.* (1951) and Robertson *et al.* (1951)—have shown that the number of eggs ovulated increases with the number of heat periods after the attainment of puberty. Thus if the topcross gilts have more nearly approached their mature physiological age at the time of breeding than have the non-topcross gilts, a difference in ovulation rate might be expected

and this could be reflected in a higher farrowing rate in the first litter. Unless the heterosis of the individual was expressed as a permanent stimulation of productivity as well as of high early productivity, the differences noted here in first litter farrowings might not be expected to be repeated in successive farrowing.

It might be postulated that breeds or lines differ in degree of expression of certain physiological characteristics which are to some extent genetically controlled. Assuming that there are such characters in swine, and that different breeds or lines are homozygous for some of the genes controlling them, crosses between such breeds or lines might result in a complementary action which could give an increase such as has been observed in these data. Such a complementary action was observed by Hammond (1934) from crosses of two inbred strains of rabbits which showed relatively low fertility due to different causes. One of the strains had high ovulation rate and high embryo mortality; the other strain had low ovulation rate, with low mortality. When the two strains were crossed, the F_1 females had a high ovulation rate and a low embryo mortality, so that they gave birth to more young than either of the parent strains.

On the assumption that the topcross-non-topcross results presented here are representative, it would appear that there is some non-additive genetic diversity between the average outbreds and some of the inbred lines. The results from crossbreeding (Winters *et al.*, 1935; Lush *et al.*, 1939; Hutton and Russell, 1939; Robison, 1948) and linecrossing (Dickerson *et al.*, 1946; Warwick and Wiley, 1950; Sierk and Winters, 1951; Chambers and Whatley, 1951) point to the same conclusions as far as non-additive genetic diversity of breeds and of lines is concerned.

The fact that only the lines derived in part or all from Landrace or Yorkshire foundation stock sired gilts which farrowed and weaned significantly more pigs than the non-topcross gilts when the comparisons were made line by line, suggests that the prolificacy of the parent lines and/or the diversity of the cross may be important factors in the reproductive capacity of the topcross gilts. There was little evidence from the productivity records of these parental inbred lines that the superior performance of these topcross gilts could be assigned to an additive contribution of the sires from these lines unless the effective environment under which the inbreds developed was considerably poorer than that experienced by the topcrosses on the farms. Evidence that this non-additive genetic diversity is not found to the same extent within groups as between groups may be seen by con-

sidering the estimates of the degree of heritability and repeatability in sow's productivity within breeds in the light of the results from crossing.

The estimates of heritability of sow's productivity as given by Hetzer *et al.* (1940), Stewart (1945), Cummings *et al.* (1947) and Blunn and Baker (1949) are low enough to indicate little genetic effect (mainly additive) on fertility within lines or breeds but the results of crossing show that the genetic influences on the gilt productivity complex is rather large in combinations of lines and breeds and in topcrosses.

The work done on the repeatability of litter size by Hetzer *et al.* (1940), Lush and Molln (1942), Blunn and Baker (1949), and Stewart (1945) indicates that the repeatability of litter size is of about the same magnitude as heritability. This fact might seem to indicate that dominance, over-dominance and non-allelic gene interactions are not very important factors in determining genetic differences in litter size within lines or breeds. Hereditary differences within breeds due to dominance, over-dominance or epistacy would not be included to the same extent in heritability estimates as they would in estimates of repeatability. These two statistics are not directly comparable, however, inasmuch as in most studies heritability is obtained from the correlation between first litters of dams and daughters, whereas repeatability involves at least two farrowings per sow. Anything unique about the first litter performance might tend to limit the comparability of these two statistics since, even though the sow's genetic make-up has not changed, its expression may not be the same in successive litters. Even so, there is not much indication of genetic control of variation in litter size from intrabreed repeatability studies.

From this reasoning it would appear that the genetic effects observed here may be characteristic of crosses of diverse stocks. The offspring from a cross are, on the average, undoubtedly heterozygous for more loci than the individuals within the groups from which they were derived and may also have non-allelic combinations not common within the crosses. The crosses would therefore be more likely to provide a basis for allelic and non-allelic gene interaction not commonly occurring within the groups from which they were derived.

Since tests for combining ability were not made before the inbreeding and development of the lines were begun, it is not possible to say whether it is the inbreeding that has tended to make any of these lines diverse from other stocks, or whether such lines were superior or inferior ones for combining ability before the inbreeding began. These tests do, however, show that, either by chance or by plan, in

the selection of the foundation stock, in the inbreeding, in the selection during the development of the lines, or by combinations of these factors, it is possible to isolate lines whose boars mated to outbreds produce better performing progeny than outbreds mated *inter se*.

Summary and Conclusions

Differences between the progeny (topcross) of inbred boars and the progeny (non-topcross) of non-inbred boars bred to non-inbred sows have been studied in 44 farm herds.

Thirty-eight inbred boars representing several inbred lines were used in these intra-farm comparisons. Records were obtained on 1968 pigs from 314 litters sired by inbred boars and 2351 pigs from 366 litters sired by non-inbred boars.

The variables studied in the comparisons of topcross and non-topcross litters were number of pigs farrowed, number weaned, number alive at 5 months of age and the percentage viability from birth to 154 days. Individual weaning weights, gains from weaning to 5 months of age and 5 month weights were studied on the topcross and non-topcross pigs. Data were also collected on the productivity of 200 topcross and 238 non-topcross gilts. Ovulation rates were recorded on topcross and non-topcross gilts representing one line.

Pounds of feed per pound of gain and carcass information were collected from samples of topcross and non-topcross pigs farrowed and raised to weaning on farms and then brought to the University farm and fed from 72 days of age to a weight of 210 pounds. Progeny of three inbred lines were represented in this part of the study.

No over-all significant mean differences were found between mating systems in size of litters farrowed, weaned, alive at 5 months of age, or in percentage viability from birth to 5 months. There was no indication of differential performance among lines, with respect to mating system, for the litter size characteristics.

There were no over-all significant mean differences between mating systems for the growth characteristics, but the interaction between mating system and line for rate of gain and 154 day weight indicated that the lines were performing differentially. The eight inbred lines were combined into a high group of four lines and a low group of four lines, with respect to mating system differences in 154 day weight, and the difference between the two groups was tested for significance, making allowance for the *a posteriori* selection of the lines placed in each group. Differences in weights at 56 and 154 days of age and

gain between these ages were found to be significant when the lines were classified this way. These differences provide evidence that the lines differ in their ability to combine with outbred stocks. Analysis of the differences, done on a line by line basis, indicated that there were some lines which were significantly better than their controls in weights at weaning and at five months and in rate of gain. The presence of interaction between farm and mating system in most of the line by line comparisons indicates inconsistent results in the differences between the two kinds of progeny from those particular lines.

Data on pounds of feed per pound of gain indicated that one of the lines was siring significantly less efficient pigs than the non-topcrosses. No other differences on efficiency or on carcass information were significant.

Over-all significant differences were found in favor of the topcross gilts over the non-topcross gilts in number of pigs farrowed and weaned and in litter weaning weight. The interaction between mating system and line for number farrowed and weaned, though not significant, suggested a possible differential performance among the lines. Grouping of the same lines as were used for the growth rate analysis was made. Significant differences were found between the two groups for number farrowed and weaned, giving evidence that there is differential performance between the specific groups of lines for these two variables.

Line by line analysis showed that three of the lines were significantly higher in topcross gilt productivity than the non-topcrosses. These three lines were derived, in part or all, from Landrace or Yorkshire foundation stock, which suggests the importance of the diversity of origin of the parents in a cross. The consistency of the results for the same groups of lines in both growth and gilt productivity indicated that the heterosis tended to be expressed as a rather general physiological stimulus in these topcrosses. The over-all significant difference between mating systems for gilt productivity and the absence of such an over-all indication in the growth rate characteristics, suggests that high productivity of gilts is more generally expressed as a heterotic effect in crosses than is rate of gain.

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WOOL PRODUCTION AS AFFECTED BY THE LEVEL OF PROTEIN IN THE RATION OF THE MATURE EWE[1]

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NUMEROUS studies have been reported on the relationship of protein content in the ration to wool production. Unfortunately, the total protein content of the rations was reported in very few cases. In most cases, level of protein has been confounded with level of nutrition; i.e., a protein supplement was added to a basal ration; this action, besides increasing the level of protein also increased the intake of other nutrients. Few attempts have been made to determine the effect of amount of protein fed on wool growth through the use of isocaloric rations. Knoblich (1926) and Spöttel (1933) reported that higher levels of protein feeding increased clean wool production because of increased fiber length and thickness. Fraser (1931) observed that a "relative excess" of protein gave a 20 percent increase in raw and clean fleece weights whereas the feeding of a protein-deficient ration resulted in a 20 percent decrease in fleece weights. Bowstead and Larose (1938) found that feeding increased amounts of casein to a basal ration which permitted satisfactory gains during pregnancy had no effect on wool growth. Shrewsbury *et al.* (1943) obtained a highly significant multiple correlation coefficient for raw fleece weight on protein consumption and net energy. Several workers (Orr and Holm, 1931; Hardy and Denecke, 1931; Marston, 1932; Rees, 1934; and Meldrum *et al.*, 1948) reported increases in raw fleece weights up to 35 percent when sheep were fed protein-rich supplements to augment the native forage. Van Horn *et al.* (1950, 1951) obtained no appreciable increase in annual raw wool production when the protein content of the supplement, fed at the rate of ⅓ pound per ewe daily, was increased from approximately 10 to 39 percent during a period of three months. Leroy and Chartlet (1949) noted very

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little difference in degree of fineness but a significant difference in strength of wool between high and low levels of protein feeding.

Isocaloric rations were used by Fraser and Roberts (1933) to study the effect of level of protein on wool growth during a five-month period. One group received a daily basal ration (which previously had given good results under indoor conditions) containing 0.17 pound of digestible protein. The second group received 0.26 pound digestible protein (an increase of 52 percent) per day. They found no significant differences between the groups with respect to fiber fineness, length, or weight of wool. In fact, the low protein group produced 4.7 percent more wool than the high protein group. Similar work was carried out at the Animal Nutritional Laboratory, Adelaide (Anonymous, 1936), which indicated that changing from a basal ration containing 60 grams of protein to one containing 300 grams was attended by an increase of 145 percent in the amount of wool produced. Also, the wool changed from a 70's to 56's quality merely by increasing the level of protein fed. Jordan (1950) reported no significant differences in raw fleece weights from sheep fed rations of equal T.D.N. but containing various levels of protein.

The purpose of the present study was to determine the effect of various levels of protein feeding on wool and lamb production so that more economical supplementation could be practiced. This paper deals only with the effect of level of protein on wool production. A second paper will describe the data obtained on lamb production.

Procedure

Eighty-one 3- and 4-year-old grade Corriedale ewes with good udders, in satisfactory body condition, and with single lambs at foot, were used in this experiment. On June 14, 1949, the ewes were divided into three lots, uniform with respect to body weight, raw fleece weight, and type. The lambs were weaned on September 6, 1949. The rams were turned in with the ewes on November 7, 1949, so that lambing would begin during the first week in April, 1950. Three Corriedale rams were used on a daily rotational basis to eliminate sire effect.

Rations compounded to contain approximately 7, 10, and 13 percent total protein were fed for a period of one year commencing in June, 1949. The physical and chemical composition of rations are shown in tables 1 and 2. These rations contained approximately the same percentage of energy, fat, fiber, calcium, phosphorus, and trace elements. The rations were fed in a pelleted form to prevent selection

TABLE 1. PHYSICAL COMPOSITION OF THE EXPERIMENTAL RATIONS

(air-dry basis)

Feedstuffs	Quantity per 100 lbs. of feed		
	Lot I	Lot II	Lot III
Native prairie hay	70	70	70
Oats	15	13.5	5
Molasses	6	6	6
Starch	7	–	–
Linseed oilmeal	–	9	18
Corn oil	1.0	0.5	–
Mineral mixture[1]	1	1	1

[1] Composed of 50 lbs. NaCl, 50 lbs. $CaHPO_4$, 4 gms. KI, 11 gms. $FeSO_4$, 12 gms. $CuSO_4$, 4 gms. $MnSO_4$, and 4 gms. $CoSO_4$.

of ingredients by the sheep. All ewes were fed twice daily in individual stalls similar to those described by Harris (1949). The feed intake of each ewe was regulated to maintain or slightly increase body weight, but with the restriction that total intake of the three lots be kept at the same level. The average daily feed consumption throughout the year was 4.3 pounds per head daily in lot I and 4.5 pounds per head daily for lots II and III. Each ewe received 25,000 I.U. of vitamin A in capsule form once weekly. A mineral mixture composed of approximately 70 parts of salt and 30 parts of monocalcium phosphate was available to the ewes at all times.

An aliquot of each bag of feed used was taken. Once each month these samples were composited and analyzed for protein content.

TABLE 2. CHEMICAL ANALYSIS OF THE EXPERIMENTAL RATIONS

(dry-matter basis)

	Lot I	Lot II	Lot III
	%	%	%
Total Protein (N x 6.25)	7.5	10.4	12.6
Digestible Crude Protein	3.3	6.3	8.1
Ether Extract	4.7	4.5	4.3
Crude Fiber	27.4	27.4	26.8
Nitrogen-free Extract	52.5	49.4	47.7
Ash	7.9	8.3	8.6
Calcium	0.8	0.8	0.9
Phosphorus	0.4	0.5	0.4
Total digestible nutrients	49.1	51.7	52.1

The monthly samples were composited at the end of the trial and a complete feedstuffs analysis determined on them.

Digestion trials were run on the three rations using yearling wethers (6 yearlings were used for each ration) to determine the digestible crude protein and total digestible nutrients of these rations.[1]

The ewes were shorn the day before being put on the experimental rations and again at the completion of the trial in order that the annual wool production could be determined for that period. To study clean wool production composite samples, weighing approximately 200 grams, were taken from each fleece at shearing time. As soon as the fleece was removed from the sheep it was spread out on a slatted grading table, skirted lightly, and a representative sample drawn from the entire fleece. These samples were scoured and the percentage yield ascertained in accordance with standard laboratory procedure. Clean fleece weight, staple length, and fiber thickness were determined on these samples.

Wool samples also were obtained from measured areas on the sheep's skin to study bimonthly wool growth. A square (2 x 2 cm.) was tattooed on the flat portion of the right shoulder immediately below the point of the scapula. Six sets of wool samples from these tattooed areas were taken during the experimental period. Weight of clean wool, staple length, fiber thickness, and fiber density (number of fibers per square inch) were determined from these samples.

Results and Discussion

Total Fleece Weights

The effects of level of protein in the ration of mature ewes on total wool production are summarized in table 3. It is evident from these data that although the calorific values of the three rations were practically equivalent, higher protein feeding resulted in a considerable increase in total wool production. Raw fleece weights were significantly increased by each addition of 3 percent protein to the basal ration, amounting to approximately 16 and 25 percent. This is in general agreement with the results of other workers. Although clean fleece weights responded significantly to the first increase in protein, no further increase in weight was obtained from the ration containing 13 percent protein. This was further substantiated by the staple lengths and fiber thickness measurements on the fleece samples. The higher raw fleece weights obtained from the ewes in lot III when compared

[1] The authors are indebted to the late Dr. C. J. Watson, Division of Chemistry, Science Service, Canada Department of Agriculture, Ottawa, for conducting the digestion trials.

with lot II may be attributed primarily to a greater amount of dirt present in the fleeces. This was reflected not only in a higher dirt loss in processing but also in a lower percentage yield of clean wool. It is possible that the small increase in fiber thickness and fiber length in this lot provided an additional area on the fiber for impurities to accumulate. The plane of nutrition also may have increased the grease content of these fleeces.

TABLE 3. THE EFFECT OF LEVEL OF PROTEIN IN THE RATION ON WOOL PRODUCTION

	Lot I	Lot II	Lot III
Raw fleece weight (lbs.)	9.7	11.8**	12.1**
Clean fleece weight (lbs.)	4.8	5.6**	5.7**
Yield of clean wool (%)	50.1	49.4	46.8
Dirt loss in breaker (%)	23.2	30.0**	35.2**
Fleece staple length (mm.)	83.5	89.9**	93.9**
Fiber thickness (microns)	25.4	25.8	26.1
Density (No. fibers per sq. in.)	18216	19734	18774

** Significantly greater than lot I ($P<0.01$).

Wool Production from a Measured Area

The effects of the various levels of protein in the ration on wool production from the measured areas are summarized in tables 4, 5, and 6.

Weight of Clean Wool. The level of protein had a marked influence on the average weight of clean wool obtained from a measured area (see table 4). The higher level of protein received by lot II in relation to lot I resulted in a highly significant increase in weights of clean wool (26 percent) but further supplementation did not produce a significant increase. In general, this confirmed the results obtained from the analysis of clean fleece weights.

It is also evident from the data in table 4 that variability in average production between periods was very great. During the period of advanced lactation and after weaning (August–October, 1949) clean wool production was greater than that produced during the previous period when the ewes were lactating. By October maximum growth had been reached and was maintained until December, 1949. The decrease during the following period (December–February) was highly significant and may be attributed primarily to the extremely cold weather that prevailed during that time (an average of —11° F., for

40 days). Ferguson *et al.* (1949) found that the environmental temperature had a significant positive association with rate of wool growth. However, early pregnancy also may have contributed to the decline during this period. A further decrease, which was highly significant, occurred from February to April, this being the period of advanced pregnancy. A final depression (also highly significant) occurred during the last two-months period of the experiment when lactation was at its maximum.

TABLE 4. THE EFFECT OF LEVEL OF PROTEIN IN THE RATION ON THE WEIGHT OF CLEAN WOOL TAKEN FROM A 4 SQ. CM. AREA

	Av. Weight of Wool (mg.)			Period
Period	Lot I	Lot II	Lot III	Means
June 16–Aug. 15, 1949	115.3	130.7	130.7	125.6
Aug. 16–Oct. 14, 1949	155.6	181.2	178.4	171.7
Oct. 15–Dec. 13, 1949	145.0	181.8	188.2	171.7
Dec. 14–Feb. 11, 1950	134.4	169.0	171.1	158.2
Feb. 12–Apr. 12, 1950	84.7	117.5	130.1	110.8
Apr. 13–June, 11, 1950	50.9	86.4	93.6	77.0
Lot Means	114.3	144.4	148.7	
Least Significant Differences:		5[1] Percent	1[1] Percent	
Between lot means (mg)		8.4	11.9	
Between period means (mg)		11.8	16.8	

[1] Levels of probability.

Fiber thickness. The mean fiber thicknesses of the bimonthly wool samples are presented in table 5. An analysis of variance showed that significant differences in fiber thickness were obtained between lots and periods of growth. The fiber thicknesses produced by lots II and III were significantly greater ($p<0.01$) than lot I. However, the higher level of protein received by lot III did not increase the fiber thickness significantly above that of lot II. Apparently, the ration containing 10 percent protein produced a fiber thickness closely approaching the maximum genetically possible for these sheep.

The effect of weaning, pregnancy, and lactation on fiber thickness was very similar to that on the bimonthly weights of clean wool. However, the severe weather experienced during December-February, 1950, did not decrease fiber thickness significantly.

Fiber length. The mean fiber lengths grown bimonthly are presented

TABLE 5. MEAN FIBER THICKNESS OF THE BIMONTHLY WOOL SAMPLES AS AFFECTED BY LEVEL OF PROTEIN IN THE RATION

Period	Mean Fiber Thickness (Microns)			Period Means
	Lot I	Lot II	Lot III	
June 16–Aug. 15, 1949	22.73	23.08	23.74	23.18
Aug. 16–Oct. 14, 1949	24.58	24.86	25.15	24.86
Oct. 15–Dec. 13, 1949	24.22	25.45	26.10	25.26
Dec. 14–Feb. 11, 1950	23.96	24.97	25.50	24.81
Feb. 12–Apr. 12, 1950	21.72	23.22	23.79	22.91
Apr. 13–June, 11, 1950	19.12	21.82	22.87	21.27
Lot Means	22.72	23.90	24.52	

Least Significant Differences:	5[1] Percent	1[1] Percent
Between lot means (microns)	0.76	1.08
Between period means (microns)	1.08	1.53

[1] Levels of probability.

in table 6. Unlike the results of the previous analyses of weights of clean wool and fiber thicknesses, staple length showed highly significant increases for each increase in level of protein fed. The length of fiber produced was directly proportional to the amount of protein received.

Like the total weight of clean wool and fiber thickness, the period during which the wool was grown had a highly significant effect on the actual length of fiber grown. During the period of advanced lactation

TABLE 6. MEAN FIBER LENGTH OF BIMONTHLY WOOL SAMPLES AS AFFECTED BY LEVEL OF PROTEIN IN THE RATION

Period	Mean Fiber Length (mm)			Period Means
	Lot I	Lot II	Lot III	
June 16–Aug. 15, 1949	19.0	19.8	20.6	19.8
Aug. 16–Oct. 14, 1949	21.0	21.6	22.6	21.7
Oct. 15–Dec. 13, 1949	21.0	22.0	22.8	21.9
Dec. 14–Feb. 11, 1950	20.6	21.3	22.2	21.4
Feb. 12–Apr. 12, 1950	18.1	19.6	20.9	19.5
Apr. 13–June, 11, 1950	17.1	19.4	20.4	19.0
Lot Means	19.5	20.6	21.6	

Least Significant Differences:	5[1] Percent	1[1] Percent
Between lot means (mm)	0.5	0.8
Between period means (mm)	0.8	1.1

[1] Levels of probability.

and after weaning (August 16-October 14, 1949) the increase was highly significant. Later, advanced pregnancy significantly reduced fiber length. Burns (1931, 1931a) observed that the monthly wool growth (length of fiber) of Rambouillet and Hampshire sheep was remarkably uniform throughout the year. In his study advanced pregnancy and lactation had no pronounced effect on longitudinal growth. Bell *et al.* (1936) concluded from linear measurements that the rate of wool growth was influenced by parturition and lactation but not by pregnancy.

Interrelationship of clean weight of wool to fiber length, fiber thickness, and density of fibers. It was noted in the previous analyses that highly significant increases were obtained in fiber length, fiber thickness, and weight of clean wool when the protein content of the ewe's ration was increased from 7 to 10 percent. Increasing the protein

TABLE 7. TOTAL WEIGHTS OF WOOL FROM A MEASURED AREA, CLEAN FLEECE WEIGHTS, AND THEIR RESPECTIVE COEFFICIENTS OF CORRELATION

	No. of Sheep	Wt. of Wool from 4 sq. cm.	Ave. Clean Fleece Wt.	Coefficients of Correlation
Lot I	23	683	4.9	0.91**
Lot II	26	867	5.6	0.68**
Lot III	27	892	5.8[1]	0.87**

[1] Average weight slightly higher than reported in table 3 since it includes the weight of one dry ewe not previously considered.
** Statistically significant ($P<0.01$).

intake from 10 to 13 percent resulted in a highly significant increase in fiber length, and small, but non-significant increases in weight of clean wool and fiber thickness. Density of fibers on the skin was slightly greater in lot II than in lots I and III, although the differences were not significant. The extent to which weight of clean wool is influenced by length, thickness, and density of fibers from a measured area cannot be fully assessed from the data presented in this paper. A detailed analysis of these interrelationships will be published in a future paper.

Relation of weight of wool from a measured area to clean fleece weight. Coefficients of correlation were calculated for the clean fleece weights and the total weights of clean wool obtained from the 4 sq. cm. areas. These data, together with the average weights of wool, are shown in table 7.

Highly significant coefficients of correlation were obtained between these two weights of wool for each lot, and would indicate that the error in taking the samples from the tatooed areas was extremely small. It

also would indicate that samples from a given area could be used as an index of total clean wool production. The reliability of such an index is receiving further study and will be presented in a future paper.

Summary and Conclusions

Pelleted isocaloric rations containing 7, 10, and 13 percent protein were fed to mature ewes for a period of one year to study their influence on wool production. From the data presented the following conclusions seem justified.

1. Increasing the level of protein from a basal ration containing 7 percent protein to 10 and 13 percent produced significant increases in raw fleece weights.
2. Highly significant increases in clean fleece weight were obtained from ewes on 10 and 13 percent protein rations as compared to ewes on the ration containing 7 percent protein. No difference was observed in the clean wool production from the two groups receiving the 10 and 13 percent protein rations.
3. The weight of clean wool obtained from a measured area (2 x 2 cm.) confirmed the results obtained from the clean fleece weight data. Increasing the protein content from 7 to 10 percent produced a highly significant increase in clean weight but further supplementation resulted in only a slight non-significant increase. Advanced pregnancy, lactation, and temperature, significantly influenced the amount of clean wool produced from these areas.
4. Fiber thickness was significantly increased by raising the level of protein in the ration to 10 and 13 percent. Increasing the level from 10 to 13 percent gave no further response. Advanced pregnancy and lactation, but not temperature, influenced fiber thickness.
5. The length of fiber produced on measured areas was found to be directly proportional to the amount of protein fed. Highly significant increases in fiber length were obtained for each increase in level of protein. Advanced pregnancy significantly reduced length growth in all three lots.
6. Weight of clean wool from a measured area was found to be closely related to total clean wool production.
7. On the basis of these results it was found that 10 percent protein (0.23 pound of digestible crude protein per head daily) in the ration of mature breeding ewes was adequate for maximum clean wool production.

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LAMB PRODUCTION AS AFFECTED BY LEVEL OF PROTEIN IN THE RATION OF THE MATURE EWE[1]

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IN a previous paper Slen and Whiting (1952) indicated that very little information was available on the minimum protein requirements of sheep for maximum wool production. It was pointed out that in practically all of the published literature on this subject, level of protein had been confounded with level of nutrition and consequently it was not possible to ascertain whether the differences in the data reported resulted from increased protein feeding or from an increased plane of nutrition. A similar situation was found in the literature on level of protein as related to lamb production. Only a few experiments have been reported which were designed to determine the amount of protein required during pregnancy and none have been reported, to the authors' knowledge, to determine the protein requirement during lactation. Such information is desirable in formulating rations for pregnant and lactating ewes and for effective supplementation of ewes on the range.

Van Horn *et al.* (1950, 1951) found no marked influence on birth weights or weaning weights of lambs from ewes that were supplemented daily on the winter range with 1/3 pound of pelleted concentrates varying in protein content from 10 to 37 percent. In these experiments some additional feed was given the ewes because of bad weather and poor condition of the ewes. All ewes were removed from their experimental rations a few days before lambing and fed a 20 percent protein pellet and alfalfa hay ration.

Jordan (1950) reported that increasing the digestible crude protein intake of pregnant ewes from 0.14 to approximately 0.33 pound daily (average weight of ewe approximately 135 pounds), when receiving rations equivalent in total digestible nutrients (1.75 pounds TDN daily), did not influence appreciably birth weights of lambs or their

[1] Contribution from the Experimental Farms Service, Canada Department of Agriculture, Ottawa. Part of a thesis submitted by the senior author to the Graduate School, University of Wyoming, Laramie, Wyoming, in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

[2] The authors wish to acknowledge the assistance of Mr. J. Orr, herdsman, in conducting this experiment.

[3] Lethbridge, Alberta.

gains during the first 50 days. In these experiments an additional 0.4 pound of corn was fed per ewe daily during the last 28 days of the experiment. All ewes were removed from their experimental rations a few days before lambing started and were fed corn and alfalfa hay.

Klosterman *et al.* (1951) reported no consistent differences in lamb production from ewes fed rations approximately equal in total digestible nutrients (approximately 2.6 pounds of TDN per day) but which varied from 6.8 to 11.0 percent total protein (0.12 to 0.31 pound of DCP per ewe daily). The average initial weight of the ewes used in these experiments was approximately 135 pounds. These workers also reported that pregnant Shropshire ewes averaging 135 pounds in body weight remained in positive nitrogen balance, made satisfactory gains, and gave birth to thrifty lambs when fed an average of 0.10 pound of digestible crude protein per ewe daily (TDN intake was approximately 1.76 pounds per ewe daily).

The National Research Council's recommended allowance of digestible crude protein for sheep (Pearson *et al.*, 1949) weighing 130 pounds is 0.20 pound during the first 100 days of gestation, 0.23 pound during the last six weeks before lambing, and 0.30 pound during lactation. These recommendations are based mainly on data obtained from cattle.

The purpose of this study was to determine the effects of various levels of protein feeding on wool and lamb production. Only the data pertaining to lamb production are presented in this paper.

Procedure

Eighty-one 3 and 4-year-old grade Corriedale ewes were used in this experiment. All ewes had sound udders, were in satisfactory condition, and had a single lamb at foot when placed on experiment in June, 1949. They were divided into three uniform groups and fed pelleted rations containing approximately 7, 10, and 13 percent total protein (3.3, 6.3, and 8.1 percent digestible crude protein) for a period of one year. Details regarding rations fed, methods of feeding, and handling of the ewes were discussed in a previous paper (Slen and Whiting, 1952). The lambs were weaned from the ewes in September and the ewes were bred to lamb commencing around April 1, 1950. Each lamb was weighed within 12 hours after birth and at weekly intervals thereafter, until 6 weeks of age. The ewes were weighed within 12 hours after lambing. The experiment was concluded on June 14, 1950, immediately after the ewes were shorn. However, most of the ewes and lambs were retained on the station after the completion of the project and monthly weights were obtained on the lambs until weaned.

Results and Discussion

Feed Intake and Body Weights of Ewes

Monthly feed consumption (pounds of air-dry feed) of the three lots of ewes remained approximately the same from the beginning of the experiment until about six weeks before lambing. The feed allowance was reduced for all ewes during February as they were becoming very fat. During the last two to three weeks of gestation many of the ewes on

TABLE 1. AVERAGE DAILY INTAKE (POUNDS) OF DIGESTIBLE CRUDE PROTEIN AND TOTAL DIGESTIBLE NUTRIENTS BY EWES FED 3 LEVELS OF PROTEIN

Period	Lot I (7% protein)	Lot II (10% protein)	Lot III (13% protein)
June 1949 to 6 weeks before lambing			
DCP	0.13[1] (0.20)[2]	0.25 (0.20)	0.33 (0.20)
TDN	2.0 (2.0)	2.1 (2.0)	2.1 (2.0)
Last 6 weeks of gestation			
DCP	0.13 (0.24)	0.23 (0.25)	0.29 (0.25)
TDN	1.7 (2.4)	1.9 (2.5)	1.9 (2.5)
During lactation			
DCP	0.12 (0.30)	0.23 (0.30)	0.29 (0.30)
TDN	1.6 (2.8)	1.9 (2.9)	1.9 (2.9)

[1] DCP calculated from the protein content of the ration fed during each period and the average protein digestibility coefficients obtained on these rations. The protein content of the rations varied within ± 1 percent of the average.

[2] Numbers in parentheses are the recommended allowances of the National Research Council.

the low-protein ration developed poor appetites. As a result it was not possible during this period to maintain the feed consumption as high as planned. Many of the ewes did not regain their appetite until about three weeks after lambing. Consequently, total feed intake for lot I was somewhat lower than for lots II and III.

The average daily intake of digestible crude protein and total digestible nutrients of the three lots are shown in table 1. Also shown in this table are the recommended allowances of the National Research Council for total digestible nutrients and digestible crude protein (Pearson *et al.*, 1949) for ewes weighing the same as those in this experiment. The average body weights at various intervals are shown in table 2. It

will be noted from these two tables that although the ewes in lot I received considerably less digestible crude protein during early pregnancy than the recommended allowance of the National Research Council, they gained practically as much as those receiving considerably more protein. Also, during the period between six and two weeks before lambing all ewes continued to gain even though receiving about 75 percent of the recommended allowance of total digestible nutrients. No doubt this increase was largely fetal growth. During the last two weeks of gestation only the ewes in lot III received the recommended allowance for protein and none of the lots received the recommended allowance for total digestible nutrients. The ewes in lots II and III lost more weight during lactation than lot I. This was accounted for in

TABLE 2. AVERAGE BODY WEIGHTS (POUNDS) OF EWES FED RATIONS CONTAINING 7, 10, AND 13 PERCENT TOTAL PROTEIN

	Lot I	Lot II	Lot III
June 1949 (initial wt.)	117	117	117
Breeding season	128	127	128
6 weeks before lambing	154	160	160
2 weeks before lambing	160	168	171
Immediately after lambing	135	150	152
June 1950 (final weight)	128	135	135

that some ewes in lots II and III were nursing twins while no ewes in lot I were nursing twins and some were dry, having lost their lamb.

On the basis of the body weights of these ewes it would seem that the recommended allowances of the National Research Council for total digestible nutrients are higher than required to allow for 10 to 20 pounds increase in weight during pregnancy, and a normal loss of approximately one pound per week during early lactation. Also, these recommended allowances for digestible crude protein are higher than required during early pregnancy and probably also higher than required during the latter part of pregnancy and lactation.

Birth Weights and Gains of Lambs

The number of lambs born and the average birth weights are shown in table 3. Both the single and twin lambs from the ewes receiving the higher levels of protein were significantly heavier than the lambs from

ewes receiving the low-protein ration. There were no significant differences in birth weights of lambs from the ewes in lots II and III indicating that the extra protein fed to lot III was of no additional value in increasing these weights. Many of the lambs from the ewes on the low-protein ration were weak at birth, three ewes of the 24 lambing in this group had no milk, another six ewes had insufficient milk to nurse one lamb, and none had sufficient milk to raise twin lambs. All twin lambs were allowed to remain with their mothers for 24–36 hours after birth.

TABLE 3. NUMBER OF LAMBS BORN AND AVERAGE BIRTH WEIGHTS OF LAMBS AS INFLUENCED BY LEVEL OF PROTEIN IN THE RATION OF MATURE EWES

	Lot I	Lot II	Lot III
No. ewes bred	27	27	27
No. ewes lambed	24[1]	27	26[2]
No. lambs born	33	42	42
No. lambs alive at birth	33	40	41
Av. birth weights (lbs.)			
Singles	9.5	11.4*	11.0*
Twins	7.5	8.6**	9.0**
All lambs	8.3	9.4*	9.4[3]*
Wt. lamb per ewe lambed	11.9	14.6**	15.2**

[1] Three ewes died during latter stages of pregnancy due to pregnancy disease. These ewes were carrying twin lambs.
[2] One dry ewe in this lot.
[3] Includes one set of triplets.
* Significantly heavier than lambs in lot I ($P<0.05$).
** Significantly heavier than lambs in lot I ($P<0.01$).

At the end of that time, if it was apparent that there was insufficient milk to satisfactorily raise both lambs, one was destroyed. All single lambs and most of the twin lambs born in lots II and III were strong at birth and all ewes, with the exception of one, had sufficient milk for at least one lamb.

It is evident from this experiment that 0.13 pound of digestible crude protein during pregnancy was not sufficient to produce a vigorous lamb and/or sufficient milk to nurse the lamb. This finding does not agree with Klosterman *et al.* (1951), who reported that 135-pound ewes receiving 0.10 pound digestible crude protein made satisfactory gains and produced thrifty lambs (TDN intakes of the ewes in this experiment and in that of Klosterman *et al.* were approximately the same). However, it should be mentioned that 15 of the ewes on the low-protein

intake did produce reasonably thrifty lambs and had sufficient milk to raise one lamb. Apparently 0.13 pound of digestible crude protein daily furnished at least the minimum protein requirements of these ewes.

The average weights of lambs at 6 weeks of age and at weaning are shown in table 4. The single lambs and twin lambs raised as singles in the two higher protein groups were heavier at 6 weeks of age and at weaning time than lambs raised in the low-protein group. Lambs in lot II (10 percent total protein) made slightly greater gains than lambs in lot III (13 percent total protein) indicating that there was no additional value in stimulating milk flow from the extra protein consumed. On the basis of lamb gains the recommended protein allowance of the National

TABLE 4. THE AVERAGE WEIGHTS (POUNDS) OF LAMBS AT 6 WEEKS OF AGE AS INFLUENCED BY THE PROTEIN INTAKE OF THE EWES

	Lot I	Lot II	Lot III
Weights at 6 weeks of age			
Born singles, raised singles	27.6(9)[1]	34.3(12)	33.4(10)
Born twins, raised singles	27.4(6)	32.8(6)	32.9(6)
Born twins, raised twins	—	25.4(6)	24.1(12)
All lambs	27.5(15)	31.5(24)	30.1(28)
Av. daily gain to six weeks	0.44	0.51	0.48
Weight at weaning (Sept. 6)	59.8	67.5	65.8

[1] Numbers in parentheses are the number of lambs in each group.

Research Council during lactation seemed to be higher than required for the ewes in this experiment. However, for those breeds of sheep that normally raise twin lambs these recommended allowances may be required.

Only 15 lambs in lot I survived to 6 weeks of age. Of the 33 lambs alive at birth 15 were destroyed soon after because the ewes had insufficient milk to nurse them, one died of apparent starvation, and two died from unknown causes. Ten lambs were destroyed shortly after birth in lot II because the ewes had insufficient milk to carry twin lambs and six died from unknown causes, presumably from eating dirt. Seven lambs were destroyed shortly after birth in lot III because the ewes had insufficient milk to raise twin lambs (in one case triplets), and six lambs died from unknown causes, presumably from eating dirt. The lambs that died were making good gains until shortly before death.

The gains in weight of the lambs in the three groups from 6 weeks of

age to weaning time were approximately the same. During this period the lambs had access to medium-good pasture but the ewes were fed in dry lot.

Pregnancy Disease

Three ewes in lot I died during the last week of gestation. Cause of death was diagnosed as pregnancy disease. These ewes were in very good condition when they died but had developed poor appetites during the previous two weeks. A number of other ewes in lot I showed some symptoms of this condition but recovered after being fed a small quantity of beet molasses daily. Whether the ketosis was due to the low-protein intake or to temporary inanition is not known. Saarinen and Shaw (1950) have indicated that in dairy cows fatty infiltration of the liver associated with spontaneous ketosis is due for the most part to inanition. They also reported that fasted cows which received a low-protein ration both before and after parturition exhibited livers with a higher fat content than cows on higher protein content.

Summary

Three groups of 27 mature ewes were fed individually for a period of one year, rations containing 7, 10, and 13 percent total protein (3.3, 6.3, and 8.1 percent digestible crude protein), to study the influence of protein intake on body weight of the ewes and birth weight and growth of the lambs.

Body weight increases of the ewes receiving the three levels of protein in their rations were approximately the same until the latter part of the gestation period when the ewes receiving the low-protein ration did not gain as rapidly as the two groups receiving higher levels. There was no difference between the group receiving 10 percent total protein in the ration and the group receiving 13 percent total protein.

Birth weights of the lambs from ewes receiving the low-protein ration were significantly less than from the ewes receiving the higher protein rations. Birth weights were not influenced by increasing the total protein content of the ration from 10 to 13 percent.

Lambs from ewes receiving 10 and 13 percent protein gained more during the first six weeks after birth than lambs from ewes receiving the low-protein ration.

Some of the ewes on the low-protein ration had insufficient milk to nurse single lambs and none had sufficient milk for twin lambs with the

exception of one. All ewes receiving the two higher levels of protein had sufficient milk for one lamb and many had sufficient for twins.

On the basis of the results of this one experiment the recommended allowances of the National Research Council for digestible crude protein during early pregnancy and lactation appear to be somewhat higher than is required.

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DEVELOPMENT OF A FEED FROM THE CREOSOTE BUSH AND THE DETERMINATION OF ITS NUTRITIVE VALUE

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THE creosote bush, *Larrea divaricata* Cav., the most common desert shrub of the Southwest, dominates about 20 million acres from west Texas to California. Although the plant itself is unpalatable to livestock, the lands it occupies are generally used for grazing cattle. The carrying capacity of such land is sometimes as low as 0.1 head per section, and rarely more than two. Analyses of the twigs and leaves of the creosote bush show that they contain large amounts of protein and other nutrients. It seemed possible that they might constitute a greater potential supply of feed than is being obtained through the grazing of the area (table 1).[3]

An investigation was undertaken, therefore, to determine means of rendering the leaves of the creosote bush edible, to determine its nutritive value, and to obtain information concerning the potential practical importance of the resulting feed.

Experimental Results

It was found that both the bitter taste and the disagreeable odor of creosote bush leaves could be removed by extraction with ethyl alcohol. The residual meal after drying was edible for sheep, cattle, and goats without any additions. During the first few days of feeding, however, it was necessary to mix the meal with decreasing amounts of alfalfa. The average intake per animal was about 3 pounds of dry matter per day.

The carcass of a wether, fed extracted creosote bush meal for 30 days, was found to be fat, in good condition, and did not possess any unusual odors or flavors. Milk from a cow and a goat fed the meal for ten days was of good quality and of normal flavor.

Extracted creosote bush meal was subjected to proximate, mineral, carotene and amino acid analysis by conventional methods. The results are compared with literature values for alfalfa in tables 1 and 2.

[1] The author would like to express his appreciation to Professors W. E. Watkins, Marvin Koger and P. E. Neale of the Animal Husbandry Department for their helpfulness in many ways.

[2] Chemistry Division of the New Mexico Agricultural Experiment Station.

[3] No published reports have been found of previous attempts to utilize the creosote bush as a feed. In 1950, however, Mr. S. W. Casner, a Texas rancher stated to the author that he had found the leaf palatable to cattle after it had been extracted with dilute alkali and neutralization. The only ill effect he had noted was abnormal scouring.

TABLE 1. COMPARISON OF CHEMICAL CONSTITUENTS OF ALFALFA AND CREOSOTE BUSH LEAF[1]

	Non-Feed Stuff	Feedstuff	
Constituent[2]	Unextracted Creosote Bush Leaf	Ethyl Alcohol Extracted Creosote Bush Leaf	Alfalfa[3]
Crude Protein %	14.6	16.6	16.3
Ether Extract %	18.1	2.8	2.2
N-Free Extract %	44.4	48.7	40.4
Crude Fiber %	13.4	18.2	32.0
Total Ash %	9.5	13.7	9.1

[1] Sample includes small twigs (Sampling method of Mallery (1950)).
[2] Results on moisture free basis.
[3] Average of 898 samples—Morrison (1948).

TABLE 2. MINERAL,[1] CAROTENE, AND AMINO ACID ANALYSES OF EXTRACTED CREOSOTE BUSH FEED AND ALFALFA HAY

	Extracted Creosote Bush Feed	Alfalfa Hay[3]
Moisture[2]	7.6%	9.5%
Sodium	0.10%	0.13%
Potassium	1.39%	2.05%
Calcium	2.52%	1.47%
Magnesium	0.10%	0.29%
Iron	0.04%	0.025%
Chlorine	0.03%	0.37%
Sulfur	0.29%	0.32%
Phosphorus	0.26%	0.24%
Ca/P Ratio	9:1	6:1
Carotene mg./lb.	15.6	11.4
Arginine	0.57%	1.05%
Tryptophane	0.25%	0.38%
Phenylalanine	0.85%	.....
Leucine	1.50%	.....
Isoleucine	0.91%	.....
Valine	0.79%	.....
Glycine	0.83%	.....
Glutamic Acid	2.60%	.....
Aspartic Acid	1.12%	.....
Cystine	0.21%	0.36%
Tyrosine	0.62%	.....

[1] Minerals calculated on elemental basis.
[2] All results on air dry basis.
[3] Cited from Morrison (1948).

The nutritive value of extracted creosote bush meal was determined on two year old crossbred wethers using the individual metabolism crates and methods of McCall, Clark, and Patton (1943).

After a preliminary period of ten days, three consecutive test periods were run covering a total time interval of 22 days during which time the extracted meal was the sole feed. The first test of ten days and the third of four days were conducted in the metabolism crates, and feces and urine were collected. The second test was conducted out of doors in individual yard pens and only feces were collected. The sheep were able to move around in the second test and the results are only considered indicative.

The extracted meal was well mixed and several representative samples were composited and analysed. The results are shown in table 1. Feces were collected daily, weighed and ten percent removed and kept under refrigeration. At the conclusion of the test periods the composite feces sample was sprayed with a little acetic acid to prevent ammonia loss, dried in an oven at 60° C., ground and mixed and kept for analysis.

Three sheep were used in the first metabolism crate experiment. One of these did not eat satisfactory amounts of feed and was replaced on the third day. Two sheep were used for experiments two and three.

The feed, feces and urine were analysed and the results calculated to give the coefficients of apparent digestibility, nutritive ratio and nitrogen balance for each experiment. The results are listed in tables 3 and 4.

Estimated biological values were determined by using average values of other research workers for the fecal metabolic nitrogen and endogenous urinary nitrogen in accordance with the practice of Miller and Morrison (1939).

For fecal metabolic nitrogen the figure was 0.56 grams/100 grams of dry matter consumed and was averaged from the results of Miller and Morrison (1939) 0.555, Sotola (1930) 0.66, Turk, Morrison and Maynard (1934) 0.56, Morgan, Beger and Westhausser (1914) 0.51 and Harris and Mitchell (1941) 0.555. For endogenous urinary nitrogen a daily value of 0.035 grams per kilogram was averaged from the results of Harris and Mitchell (1941) 0.033, Smuts and Marais (1938) 0.035, Miller and Morrison (1939) 0.037 and Sotola (1930) 0.0331.

Since extracted creosote bush meal would probably serve as a roughage similar to alfalfa hay, it was thought the results in the foregoing tables could be evaluated better by comparing the composition and nutritive values of the two feeds.

TABLE 3. COMPARISON OF DIGESTIBLE NUTRIENTS AND COEFFICIENTS OF APPARENT DIGESTIBILITY OF EXTRACTED CREOSOTE BUSH MEAL AND ALFALFA

Test Number	Days on Test	Total Digestible Nutrients (Percent)	Digestible Nutrients (Dry Basis) (Percent)				Coefficients of Digestibility (Percent)				Nutritive Ratio
			Crude Protein	Ether Extract	Crude Fiber	N-Free Extract	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract	
Creosote Meal No. 1	10	48.1	11.0	0.0	7.0	30.1	66.8	0.0	38.5	61.7	1:3.3
Creosote Meal No. 2	8	45.9	10.1	0.0	5.2	30.6	60.4	0.0	28.3	62.9	1:3.5
Creosote Meal No. 3	4	50.6	11.3	0.0	5.3	34.0	63.1	0.0	30.8	67.6	1:3.4
Average Tests 1, 2 and 3		48.2	10.8	0.0	5.8	31.6	63.4	0.0	32.5	63.7	1:3.4
Alfalfa hay[1]		55.7	11.6	0.7	14.1	28.4	71.0	32.0	44.0	70.0	1:3.8

[1] Average results 508 trials—Morrison (1948).

Discussion

The comparative data indicate that extracted creosote bush meal approaches alfalfa in feeding value. Both feeds contain similar and adequate amounts of total and of digestible protein. Although amino acid content and protein quality are not considered too important in ruminant nutrition, it is interesting to note that the creosote bush meal contains more than the minimum percentage required for rat and chick nutrition of all the essential amino acids except arginine.

Extracted creosote bush meal contains adequate quantities of minerals and compares favorably with alfalfa. It is especially well supplied with calcium, phosphorus, sulfur and potassium. The fact that the calcium-phosphorus ratio of extracted creosote bush meal is a little high might be a disadvantage to stock having a low exposure to sunlight.

TABLE 4. AVERAGE DAILY NITROGEN BALANCES FOR EXTRACTED CREOSOTE BUSH MEAL

	Test No. 1 (10 Days)		Test No. 3 (4 days)	
	Income (Grams)	Outgo (Grams)	Income (Grams)	Outgo (Grams)
In Creosote Bush Feed	18.6		28.6	
In Feces		6.0		10.8
In Urine		11.5		14.0
Stored in Body		+1.1		+3.8
TOTAL	18.6	18.6	28.6	28.6

The carotene content of unextracted creosote bush leaf has been found to be as high as 60 mg/lb. Even after extraction it compares favorably with average values for alfalfa.

The total percentage of digestible nutrients is several percent higher for alfalfa (table 3). This is almost entirely due to the greater amount of digestible crude fiber in alfalfa. Creosote meal is higher in digestible nitrogen-free extract. The ether extract is too low to be of much significance in either feed. In the extracted meal it appears to be wholly resinous and completely indigestible.

Of great importance is the fact that the digestible protein in the two feeds is about the same. The small advantage which exists lies with alfalfa. The fairly high supplies of digestible protein are reflected in similar narrow nutritive ratios in both feeds. The positive nitrogen balances also indicate the adequacy of the digestible protein level in the extracted creosote bush feed.

The average biological value for the three tests with the extracted

creosote bush meal was 46.4 percent. This is not much lower than the 52.3 percent value for alfalfa obtained by averaging the results of Sotola (1930 and 1933) and Turk, Morrison and Maynard (1934).

The significance of these results may be questionable in the light of the suggestion by Turk, Morrison and Maynard (1934) that feeds fed alone containing fairly high protein content without high net energy content give lower biological values than the same feeds fed in medium protein and higher energy rations. Regardless of the actual significance of biological values for feeds fed alone, the fact that these two feeds containing approximately the same amounts of protein give similar values indicates a similarity in feeding value.

It appears from the foregoing that extracted creosote bush meal would have a place in livestock feeding if it could be produced competitively. The principal advantage of alfalfa seems to be its greater palatability. This might not be of extreme importance in mixed feeds containing other more palatable constituents or if flavoring aids were added to the meal.

The potential supply of the creosote bush in the Southwest seems almost unlimited. The problems of harvest and separation of leaves and wood do not appear difficult from an engineering standpoint. Martin (1945) has shown how the plants can be cut by machine while methods such as sieving, thrashing or blowing with compressed air might be used to separate the dry leaves from the branches.

Practical considerations would mean that certain areas would be more desirable for utilization than others. One such area in the Rio Grande Valley of New Mexico consists of about 400,000 acres of rather flat land in which the creosote bush cover, according to data of Gardner (1951), is about 10 percent and the area should supply about 30,000 tons of extracted meal and about 20 million pounds of resins.

Since regrowth can be expected in two to four years, (Botkin and Duisberg, 1949), this area should supply about 8,000 tons of feed per year on a sustained yield basis. This would be a net gain from land of very low value, would make it possible to increase the numbers of livestock in the local area and would be a form of insurance against excessive drought on the better range land.

It is doubtful that creosote bush could be harvested economically for the feed alone. However, it is very likely that the resins will be of value. A promising varnish has recently been produced from the resins and the resins can also be used as a source of nordihydroguaiaretic acid, a valuable antitoxidant. At the present time two small plants are extracting creosote bush for nordihydroguaiaretic acid by another method.

Summary

An edible livestock feed has been prepared from the creosote bush leaf by means of alcohol extraction. The feed has a nutritive value roughly equivalent to alfalfa. It is well supplied with important minerals, carotene, and amino acids. It is high in digestible protein and yields positive nitrogen balances in sheep feeding trials.

The feed is relatively palatable and can be fed to livestock without any additions. For best results the meal probably should be mixed with more palatable feeds.

The potential supply of the creosote bush in the Southwest is very large. It probably would not be economically practical to harvest the creosote bush for the feed alone. However, the possibilities of developing an industry utilizing the resins, nordihydroguaiaretic acid and feed values of the plant are promising.

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RANGE NUTRITION TECHNIQUES[1]

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IN the Intermountain area a major portion of the sheep subsist on the open range. In the winter they graze on semi-deserts, in the spring and fall on the foothills, and in the summer on the higher mountains. These ranges have a diversity of soil, climate, topography, and vegetation. Therefore, the sheep's diet usually is highly variable. Generally all the animal's feed supply comes from the range plants as they are selected in grazing. The diet may be deficient in essential nutrients or may actually contain an excess of certain constituents that are toxic or poisonous.

Research is needed in four phases of range nutrition before recommendations can be made to stockmen on feed supplements and management practices. These phases include (1) factors that affect the chemical composition of a given range species, (2) the botanical and nutritive composition of the sheep's diet, (3) supplementary feeding trials on a detailed experimental basis and (4) supplementary feeding trials on a practical basis using some of the most valuable supplements in various combinations, amounts, and seasons.

The first and second phases of such a study have been conducted and reviewed by Cook and Harris (1950a), Cook *et al.* (1948), and Cook and Harris (1950b). The digestibility of certain range forages has been determined by Cook and Harris (1951) and Cook *et al.* (1951) by the lignin ratio technique.

The third phase of range nutrition research can best be conducted by feeding trials in several localities in order to find the kind and amounts of supplements that should be fed to sheep to correct dietary deficiencies during various seasons. The main consideration that has prevented large scale supplementary feeding experiments is the cost of fencing a sufficient number of pastures to measure adequately the benefits. A method has been devised by the authors which uses individual portable

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[2] Chairman, Institute of Nutrition, associate professor, and professor of Range Management, respectively.
[3] Logan, Utah.

pens for feeding sheep on the range. This permits all experimental animals to graze together normally on open range and eliminates the cost of pasture fencing. It is the purpose of this report to describe the technique and the equipment used in these feeding trials.

After individual feeding trials are carried out with various supplements to correct nutrient deficiencies the most promising will be selected to be fed to large groups of sheep to determine their value from an

TABLE 1. THE COMPOSITION AND DIGESTIBILITY OF FORAGE CONSUMED BY SHEEP ON SALTBUSH RANGE IN WAH WAH AND PINE VALLEYS IN SOUTHWEST UTAH DURING THE WINTER OF 1947–48

Item	Winter range diet (dry basis)	Digestion coefficients	Digestible nutrients (dry basis)	Pregnant ewe allowance[1] (dry basis)
	%	%	%	%
Protein	7.94	42	3.33	5.56
Ether extract	4.68	66	3.09	–
N-free extract	40.9	56	22.9	–
Crude fiber	28.7	45	12.9	–
Ash	17.8	–	–	–
Cellulose	27.0	55	14.8	–
Lignin	9.52	0	0.0	–
Total digestible nutrients	–	–	46.1	60.0
Phosphorus	0.095	–	–	0.20
Calcium	2.37	–	–	0.27
Dry matter consumption	3.34[2]	–	–	3.78[2]

[1] National Research Council (1949) recommendations for a 130-pound pregnant ewe six weeks before lambing.
[2] These values are in terms of pounds.

conomical and practical point of view. This constitutes the fourth phase of the range nutrition experiments. It is planned to initiate this phase as soon as the first three phases are solved for any one locality.

Experimental

Utah's winter saltbush range is low in phosphorus and protein and relatively low in energy (table 1). Using the data in table 1 as a base, supplementary feeding trials have been conducted. In the first trials pure supplements were fed alone. Ewes of six age-classes were fed individually energy (barley), protein (soybean oil meal), and phospho-

rus (monosodium phosphate) at 2 levels giving, with one control, 7 groups. Three ewes of each age were included in each feed group, a total of 126 animals. The control sheep received only range forage. This design is adequate to measure the effect of single supplements in relation to the age of the sheep. Since arid ranges vary greatly from year

TABLE 2. EXPERIMENTAL DESIGN FOR FEEDING 3 LEVELS OF 3 SUPPLEMENTS IN ALL COMBINATIONS TO SIX AGE-GROUPS OF SHEEP, WITH ONE ANIMAL PER TREATMENT

Protein	Age of ewes in years	Phosphorus levels								
		P_0 Energy levels			P_1 Energy levels			P_2 Energy levels		
		E_0	E_1	E_2	E_0	E_1	E_2	E_0	E_1	E_2
		Number of sheep per treatment								
	Lambs	1	1	1	1	1	1	1	1	1
Pr_0	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1
	4 to 6	1	1	1	1	1	1	1	1	1
	Over 6	1	1	1	1	1	1	1	1	1
	Lambs									
Pr_1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1
	4 to 6	1	1	1	1	1	1	1	1	1
	Over 6	1	1	1	1	1	1	1	1	1
	Lambs	1	1	1	1	1	1	1	1	1
Pr_2	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1
	4 to 6	1	1	1	1	1	1	1	1	1
	Over 6	1	1	1	1	1	1	1	1	1

to year in quantity and quality of forage production, several years of replication are necessary for long-time average results.

If range forage is deficient in several nutrients, better results may be procured from feeding supplements in combinations. For this purpose the design and statistical analyses shown in tables 2 and 3 were developed. The same feeds were used as when fed separately. In addition to measuring the value of each supplement alone this design measures the effect of feeding the supplements in combinations.

Results from the use of these two experiments will be reported in a

sparate publication. The designs have given essentially the same results for the individual supplements, but the factorial design (table 2) is more efficient since it gives results on various combinations of supplements.

To carry out these experiments the sheep were herded on the open range every day, corraled at night (fig. 1) and fed every other day in individual portable pens (fig. 2, 3 and 4). The control sheep were branded with a black number on their backs and the sheep fed supplements, with a red number. After about two weeks time the red-numbered sheep readily went into the pens where they were fed the supplements (fig. 2). The supplements were weighed and placed in

TABLE 3. METHOD OF STATISTICAL ANALYSIS OF DATA COLLECTED UNDER EXPERIMENTAL DESIGN SHOWN IN TABLE 4

Source of variation	Degrees of freedom	Number of sheep to compare
Total	161	
Phosphorus (P) levels	2	54
Energy (E) levels	2	54
Protein (Pr) levels	2	54
P x E	4	18
Pr x P	4	18
E x Pr	4	18
Age of sheep (A)	5	27
A x P	10	9
A x E	10	9
A x Pr	10	9
Error	108	

small paper bags in a tray previous to feeding. No attempt was made to put a certain animal in a certain pen. Rather, the number was read and the similarly-numbered bag was selected from the feed tray and delivered to the animal. Using this procedure and 56 individual pens it was possible to feed 156 sheep in about two hours.

The sheep were weighed every 28 days with a portable platform scale and weighing crate (fig. 5). Sheep jump into the weighing crate with little assistance if the front door is raised simultaneously with the back door. Using this system the entire herd of 275 sheep can be weighed in about two and one-half hours.

If snow was not available the sheep were watered every second day with a 500 gallon tank on a two-ton truck. The portable troughs were moved every time the sheep were watered to prevent trampling of the range.

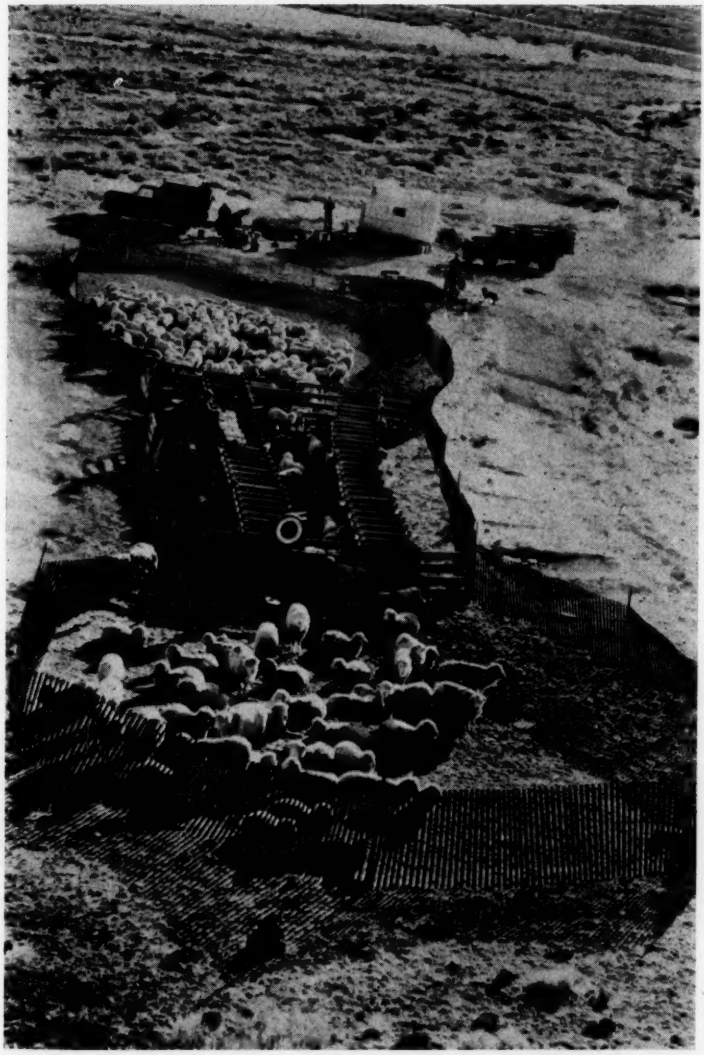

Figure 1. Portable snow fence, corrals, and pens. Portable laboratory is behind pick-up. The pens and corrals are moved every two to three weeks.

Figure 2. Sheep eating supplements from buckets. Note sacks of feed weighed out for each sheep in the tray on the ground. In some cases the monosodium phosphate was dissolved in water in a bottle and drenched down the sheep. They drank this solution readily.

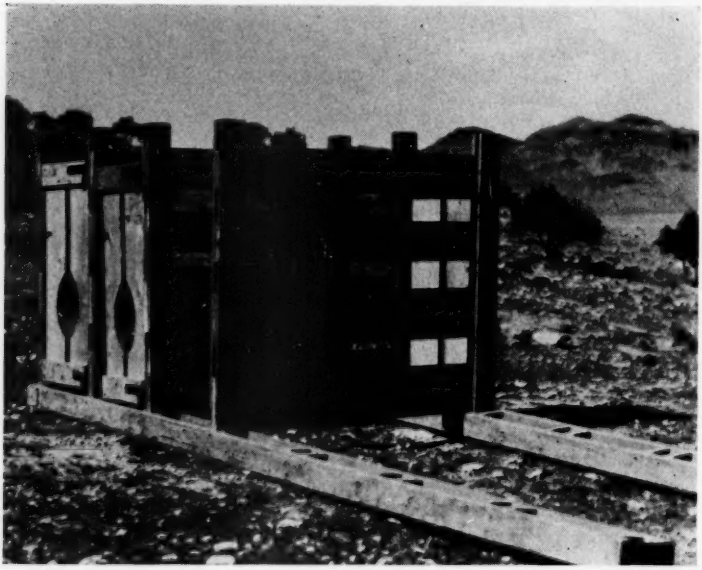

Figure 3. The pens are put together with a bottom piece, panel and two doors.

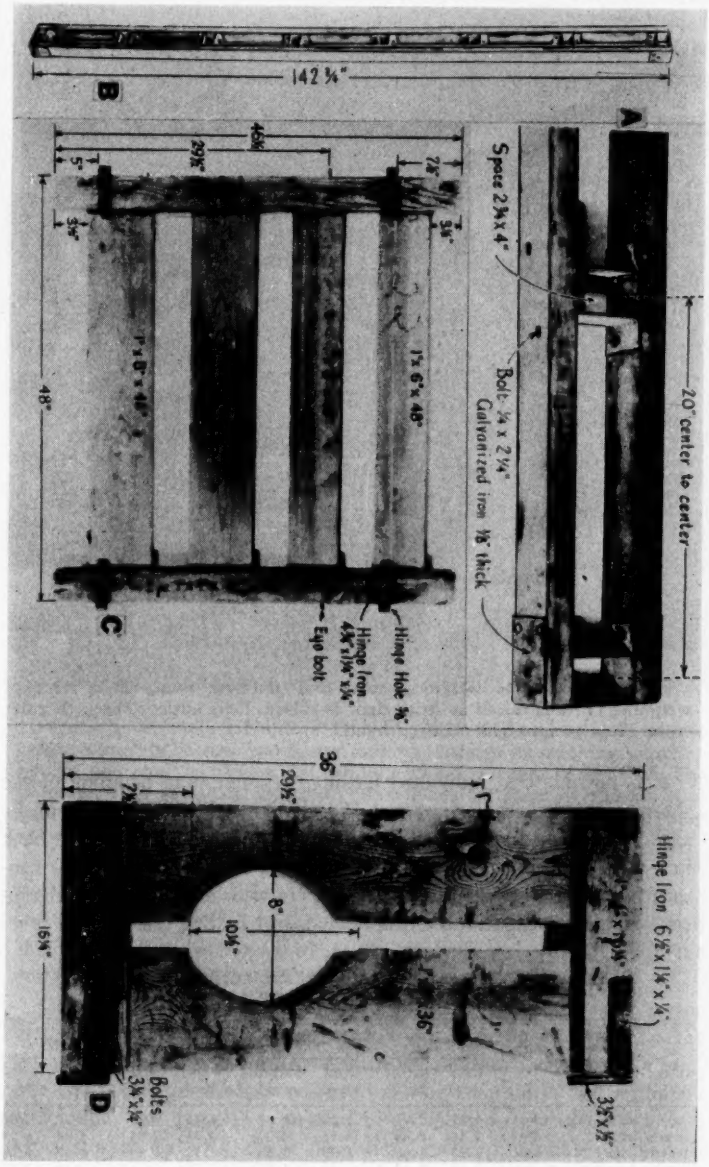

Figure 4. Detail of portable pens, A and B bottom of pens, C panel of pens and D front door of pens. The back door does not have the hole.

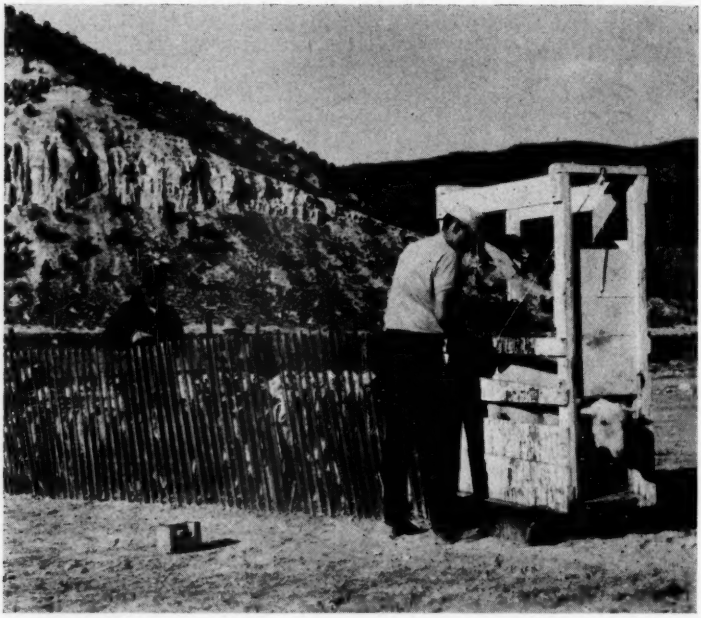

Figure 5. Portable weighing crate and platform scale. Back door of weighing crate is raised as front door is raised. This entices sheep to enter crate. Note test weight in foreground.

It is possible that individual feeding, weighing, and handling of the sheep might depress performance. To check on this point sheep of six ages were selected at random from the experimental herd and put back in a large band of sheep. The results of this comparison for three consecutive years are shown in table 4. There were no statistically significant differences between the two methods of handling the sheep.

TABLE 4. COMPARISON OF EXPERIMENTAL HERD AND LARGE BAND OF SHEEP

Item		1947		1948		1949		Average	
		Expt. herd	Large herd	Expt. herd	Large herd	Expt. herd	Large herd	Expt. herd	Large herd
Gain Nov. to May	lbs.	4.02	0.97	1.27	−0.87	3.45	5.69	2.91	2.10
Grease wool	lbs.	9.14	8.46	8.16	8.07	9.51	9.68	8.94	8.74
Scoured wool	lbs.	3.88	3.68	3.30	3.36	3.53	3.63	3.57	3.56
Staple length	in.	2.21	2.13	1.89	1.90	2.27	2.26	2.12	2.10
Lamb crop	%	114	104	92	78	89	100	98	94
Ewes lambing	%	82	88	70	66	79	77	77	77

Blood samples were taken for phosphorus, carotene, and vitamin A analyses by using a portable laboratory (fig. 6). A portable generator furnished power for the centrifuge and for shears to remove wool from the neck of the sheep before taking the blood sample and the citrated blood was centrifuged in the field to obtain plasma.

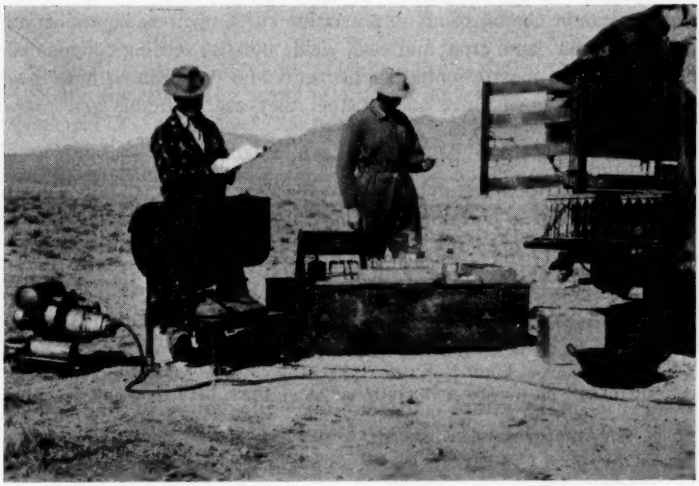

Figure 6. Portable laboratory including centrifuge, generator, pipette holder, sampling bottles, funnels for filtering, dishpan for washing sampling bottles, and other apparatus for handling blood samples in the field. The generator runs the centrifuge and power shears for shearing the necks of the sheep before taking the blood samples and also a small vacuum pump not shown here.

For phosphorus analysis, trichloracetic acid was added to the plasma and the mixture filtered in the field. The filtrate was then transported to the laboratory at Logan where the analysis was completed by the method of Koenig and Johnson (1942).

Carotene and vitamin A analyses were completed in the field by the method of Kimble (1939). A small vacuum pump operated by the portable generator was used to create a vacuum in a desicator to evaporate the pertoleum ether previous to adding chloroform and antimony trichloride. The samples were read in a Coleman colorimeter operated by a storage battery. These procedures make it possible to analyse blood in the field for carotene and vitamin A.

Summary

Range nutrition techniques involve four phases of research: (1) the nutritive value of range forage in relation to soil, site, climate, and stage of maturity, (2) the botanical and nutritive composition of the grazing sheep's diet as measured by chemical analyses and digestion trials on the range forage, (3) detailed feeding trials using several supplements or combinations to determine effect upon such production factors as gain, lamb crop, and wool yield, and (4) feeding commercial herds using the most essential supplements and determining how they can be fed on open range and whether they are profitable and practicable.

Methods have been outlined on how to carry out the third phase of such range nutrition research. This involves the use of individual portable feeding pens, a portable weighing crate, and a portable laboratory. These techniques open the way for large-scale range nutrition experiments at reasonable costs.

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INORGANIC PHOSPHORUS CONTENT AND PHOSPHATASE ACTIVITY OF THE BLOOD SERUM OF FOALS

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A HIGH negative correlation between age and the inorganic phosphorus content of the serum of growing horses has been reported by Pearson (1934). However, the earliest age represented in his data was approximately 4 months. Blunn, Howell and Caldwell (1940) have reported results of blood analyses on foals ranging in age from birth to 23 months. They state that the serum inorganic phosphorus in the foals at birth was higher than that in the dams, the average for the group of foals being 5.1 ± 0.15 mg. percent. The content was observed to rise rapidly during the first two weeks and to reach a maximum of 7.90 ± 0.33 mg. percent at about ten weeks. It thereafter gradually decreased as the animals became older, the average level at six months being 7.00 ± 0.20 mg. percent.

No data are available to indicate normal ranges of serum alkaline phosphatase activity in horses under different conditions. In view of the usefulness of information regarding serum alkaline phosphatase in the diagnosis of bone disorders in humans, it appears that too little consideration has been given to the potential value of such information in diagnosing disturbances of calcification in horses.

The physiological significance of the phosphatases and some published reports of variations, both normal and pathological, in the alkaline phosphatase content of blood serum in humans, dogs and rats have been reviewed by Moog (1946).

Alkaline phosphatase is invariably present at the sites of normal bone formation and it appears that where there is active formation of new bone there is an outpouring of the enzyme from the centers of rapid ossification into the blood. Although there are other sources of alkaline phosphatase than the centers of ossification, the content of the enzyme in the blood serum can under some conditions be taken as a measure of the rate of osteogenesis. In instances of retarded bone development, a decline in serum alkaline phosphatase has been observed. On the other hand, in rickets there is an overproduction of osteoid tissue and of

[1] Bureau of Animal Industry.

alkaline phosphatase without proper calcification. Under such conditions the phosphatase activity of the serum has been used as a criterion of the severity of the conditions and as the measure of the rate of healing.

Some observations made by Earle and Cabell (unpublished) on growing Morgan horses have indicated that serum alkaline phosphatase activity in these animals decreased from an average of about 16 Bodansky units per 100 ml. of serum at five months of age to about nine units at two years, and then more slowly with increasing years.

The data reported here are the results of some observations on variations in inorganic phosphorus and in alkaline phosphatase activity of the blood serum of foals at various intervals between birth and six months of age.

Materials and Methods

The 12 foals used for these observations were delivered by mares at the Beltsville Agricultural Research Center at different times within the course of 3 years. Two of these animals were Morgan-Thoroughbred foals that suckled their respective dams. The other 10 were Belgian foals that were used in a study of the absorption of colostrum globulins and were fed fresh mares' colostrum of known protein content, beginning at different intervals during the first 36 hours after delivery. Since the total number of animals is too small to permit any comparison of breeds and since the data obtained have indicated no trend in the kind or degree of change that could be correlated with food intake, results from all foals have been grouped together and treated on the basis of age of foal.

The two Morgan mares had occasional access to pasture during pregnancy in addition to the usual rations of hay and grain. The Belgian mares, however, were entirely stall fed on timothy hay and oats. Blood samples consisted of about 25 ml. drawn from a jugular vein.

Bodansky's procedures (1932 and 1933) were used in analyzing the blood serum for inorganic phosphorus and alkaline phosphatase activity. Results of the phosphatase determinations are therefore expressed in terms of Bodansky units.

Results and Discussion

Results of individual analyses obtained during the first seven days are plotted in figure 1 and the mean values for different age intervals up to six months are presented in table 1. The data on inorganic

phosphorus indicate that the level present immediately after birth increased markedly for about 48 hours. Thereafter, the trend was toward a continued but more gradual rise, which reached a maximum between two and three months. Following this peak the inorganic phosphorus tended to decline slowly. The mean value of 4.31 ± 0.32 mg. percent obtained within one hour after birth is lower than that

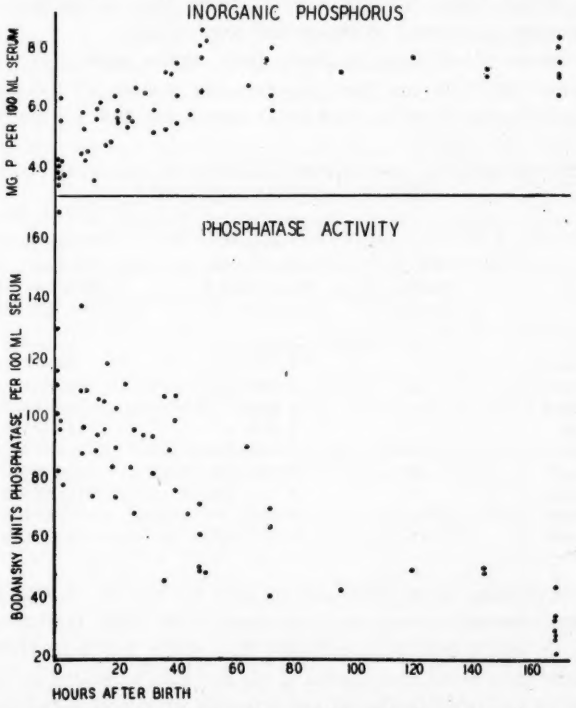

Figure 1. Results of individual analyses obtained during the first seven days.

of 5.10 ± 0.15 mg. percent reported by Blunn, Howell and Caldwell (1940) for new born foals. However, the age at which the peak was attained agrees with their observations, although the level of 8.75 ± 0.31 mg. percent presented here is somewhat higher than the peak level of 7.9 ± 0.33 mg. reported by them.

The phosphatase content or activity of the serum at birth varied in nine foals from 78 to 169 Bodansky units per 100 ml. Although the data are too scant to permit any interpretation of this wide varia-

tion among individuals, it was noted that the two lowest initial values for phosphatase (78 and 82 units) and for inorganic phosphorus as well (3.4 and 3.6 mg. percent) were in two Belgian foals that were below average in both size and vigor at birth and that subsequently grew poorly. Further, the very high value of 169 units of phosphatase was obtained in a foal that at birth appeared somewhat contracted in the digital flexor tendons in both front legs, a condition that became more aggravated as the animal grew older.

The serum phosphatase in these foals, unlike that observed by Bodansky (1934) in new born puppies, was greatest at the time of birth and decreased rapidly thereafter during the first 48 hours and

TABLE 1. INORGANIC PHOSPHORUS CONTENT AND PHOSPHATASE ACTIVITY OF BLOOD SERUM

Age of animals	No. of animals sampled	Inorganic phosphorus Mean and S.E. mg./100 ml.	Phosphatase activity Mean and S.E. Bodansky units/100 ml.
At birth	9	4.30±.32	109±9.2
8–10 hours	5	4.83±.31	108±8.3
12–24 hours	10	5.51±.15	95.1±4.4
28–48 hours	12	6.65±.31	73.5±6.0
3–5 days	8	6.91±.23	56.3±5.9
7 days	7	7.23±.25	33.0±3.9
1 month	5	7.47±.50	20.5±2.0
2–3 months	6	8.75±.31	18.5±0.8
4–5 months	6	8.12±.34	17.0±0.8
6 months	6	7.20±.40	17.3±0.9

then progressively more slowly for the next six months. A spectacular drop was observed during the early hours after birth in those individuals on which data were obtained at suitable intervals. However, this initial drop is not so apparent in the averages presented in table 1 because of the irregularities in the intervals of sampling individuals.

These observations did not indicate that the changes occurring during the first few days after birth in both inorganic phosphorus and phosphatase content of the serum were influenced greatly by the composition of the food consumed. One animal that was fed milk rather than colostrum for the first 24 hours and two that were fasted for the first eight and 12 hours, respectively, showed the same kind of change as those receiving colostrum within two hours after birth. It is believed that the changes observed are, in part at least, associated with changing metabolism in the new born animal.

Summary

Determinations of inorganic phosphorus content and of alkaline phosphatase activity have been made on blood serum obtained from 12 foals at various times between the hour of birth and six months of age. The results of these analyses for inorganic phosphorus have yielded a mean value of 4.30±0.32 mg. percent of inorganic phosphorus at birth. This level increased rapidly during the first 48 hours, then more gradually to a maximum of 8.75±0.31 mg. percent between two and three months, after which it tended to decline.

A mean alkaline phosphatase activity equivalent to 109±9.2 Bodansky units per 100 ml. of serum was observed at birth, the level declining rapidly for the first 48 hours to a mean value of 73.5±6.0 units and then progressively more slowly to a mean level of 17.3±0.9 units at six months of age.

The observations indicated that the changes in both inorganic phosphorus and phosphatase activity immediately following birth are, in large part at least, unrelated to food intake.

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RECORD OF THE PROCEEDINGS OF THE FORTY-THIRD ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

THE forty-third annual meeting of the American Society of Animal Production was held in the Hotel Sherman in Chicago on November 23 and 24, 1951, and a dinner for the honor guest was held at the Stockyard Inn on November 25. Abstracts of most of the papers presented were published in the November 1951 issue of the JOURNAL OF ANIMAL SCIENCE, Volume 10, pages 1022–1084.

PRESIDENT'S REMARKS AT OPENING SESSION

E. W. CRAMPTON

President, American Society of Animal Production

IT is not my intention to burden you with any formal address at this session. I should like, however, to make a few introductory remarks partly in explanation of the nature of the program which has been prepared for your consideration. You will no doubt have noted that not one of the speakers is or has been an animal production man, nor are the topics to be presented significant as discussions of animal production in the strict sense of the term.

In looking over the roster of our members I have been struck with the categories or disciplines which are represented now as compared to those of only a few years ago. The industry which we represent is no longer an association of animal husbandmen as it could have been described a few years ago. In increasing numbers our members, on the basis of their specialist training, would be classed as chemists, physiologists, endocrinologists, physicists, bacteriologist, or geneticists. Thus it is evident that the proportion of animal husbandmen is growing smaller.

This change in the membership is but a reflection of the expanding field covered by the animal industry.

The position and responsibility of our industry in a national emergency extends much further than the supplying of food. For example, it may be significant that the packers are now the largest producers of organic chemicals, and as such become a vital link in a defense

program. It is more than possible that the place of the livestock industry in supplying vital materials other than foods, may be of as great importance in an emergency as is food production, and may even affect policies regarding livestock production.

A rapid expansion of the livestock production involves problems of providing efficient rations. The most efficient rations for many types of livestock are so complicated and highly specialized now that the services of the feed manufacturer have become indispensable. The extent to which this is true, especially in an emergency, is frequently not realized by the man whose interests have primarily been with the production of the stock itself.

This program was prepared to stimulate thinking on the general subject of "What will be the job of the livestock industry in a National emergency." Your speakers will deal with problems related to human food production, with the production of industrial by-products, and with the role of the feed manufacturers in an expanded animal production program.

A SUMMARY OF THE MINUTES OF THE FORTY-THIRD BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

J. I. MILLER, SECRETARY
Cornell University

THE meeting was called to order in the Louis XVI Room of Hotel Sherman, Chicago, at 2:30 p.m. by President Crampton. The minutes of the 1950 meeting were not read since they had been published in the JOURNAL OF ANIMAL SCIENCE, Vol. 10(1):288–295. It was moved and seconded that they be approved as published and the motion carried.

The secretary reported that membership in the Society for 1951 consisted of 1143 domestic and 58 foreign or a total of 1201 members. In comparison with 1950, there was a gain of 66 domestic members and 10 foreign members. Subscriptions to the JOURNAL OF ANIMAL SCIENCE received during the year were 639 which was an increase of 84 over 1950. The total number of subscriptions to the JOURNAL in effect for 1951 was 713.

Since January 1, 1951, the secretary had sent three letters to the entire membership in addition to a large amount of correspondence necessary to members and subscribers in the conduct of business concerning the JOURNAL. Also, in accordance with action taken at the 1950 business meeting, the membership was balloted regarding the publishing of a proposed monograph entitled "Techniques and Procedures in Animal Production Research." The report of the voting showed that a large majority favored the publishing of the proposed monograph with financing to be through voluntary purchases only.

The treasurer's report showed that income during the year for the Morrison Award Fund amounted to $1,445.47. Expenditures amounted to $1,072.40 leaving a balance on hand November 1, 1951 of $1,664.17. As regards the general fund of the Society, there were receipts of $14,086.02 and expenditures of $17,338.28, which resulted in an operating loss of $3,252.26 for the fiscal year (November 1, 1950–October 31, 1951). This left a cash balance on hand in the general fund of $1,276.55. In addition, the Society has assets of $4,550.70 in U. S. Bonds, Series F, and $7,000.00 in U. S. Bonds, Series G.

The Auditing Committee, consisting of W. A. Craft, F. N. Andrews, and S. W. Terrill, found the treasurer's books in satisfactory order.

The editor of the JOURNAL OF ANIMAL SCIENCE, L. E. Casida, gave the following report:

"A total of 706 papers have been submitted for consideration for publication in the JOURNAL OF ANIMAL SCIENCE from its beginning 10 years ago, up through November 15, 1951. Of these, 591 have been published in volumes one through nine.

"Publication during 1951 (Volume 10) included 118 papers, the president's address and other Society proceedings of the 1950 meeting (including memorials, awards, and committee and program chairmen for 1951, 149 abstracts of papers presented at the 1951 annual meeting of the Society, subject and author indexes of Volume 10, and the usual News and Notes section in each of the four issues of the JOURNAL).

"Manuscripts received during the period from November 16, 1950 to November 15, 1951 totaled 116. Of these eight have been withdrawn or rejected, 65 have been published, 21 are in press to appear in the February 1952 issue, seven are in the process of being revised by the author, and 15 are being reviewed by the Editorial Board. (Of the 16 papers reported under revision by authors a year ago, six have not yet been accepted for publication.)

"A maximum of 87 acceptable papers became available for publication during the past year and at the same time 118 papers have been published in Volume 10 of the JOURNAL. All papers on which editorial work had been completed at the time were sent to press for each of the four issues. Publication therefore is as nearly current as possible.

"The number of papers published in each of volumes one through eight range from 39–63. In Volume 9 there were 85 and in the current volume there are 118. The number of members in the Society per published paper has fluctuated over the years but since the war, has ranged from 16.6 to 17.9. Last year it dropped to 13.2. The productiveness of the membership during 1951 increased still further; it has now developed to the place where the efforts of only 10.2 members on the average have resulted in one published paper. This change in the membership-publication ratio in addition to the increased unit cost of publication has been largely responsible for the action taken by the Executive Committee to offset costs to the Society as outlined in the August 1951 issue of the JOURNAL.

"The Editor wishes to announce that the terms of J. K. Loosli, and J. A. Whatley, Jr., on the Editorial Board will expire on December 31, 1951. The Executive Committee has appointed W. D. Gallup and L. N. Hazel respectively to replace them. The Executive Committee has also made a change in the organization of the Editorial Board by setting up again the position of Associate Editor. This position is to be filled by J. K. Loosli."

The records of the business manager of the JOURNAL OF ANIMAL SCIENCE show the following back numbers of the JOURNAL available for sale:

Volume	Year	Complete volumes	Number of copies in single issues			
			No. 1	No. 2	No. 3	No. 4
1	1942	0	0	21	29	46
2	1943	23	61	45	23	31
3	1944	0	0	0	0	0
4	1945	0	0	0	0	0
5	1946	0	0	0	0	0
6	1947	0	0	0	0	0
7	1948	21	26	24	37	21
8	1949	0	0	0	57	29
9	1950	0	0	1	73	101
10	1951	30	48	168	30	125

These back numbers may be purchased from the business manager of the JOURNAL at the following rate for the United States: Volume 10—single copies $1.75; complete volume $6.00. For preceding issues, $1.00 and $3.50, respectively. Prices elsewhere quoted on request. In addition, the following proceedings of the American Society of Animal Production are available at a cost of $1.00 each for domestic and $1.25 each for foreign.

Year	No.	Year	No.
1915–16	58	1931	73
1920	8	1932	26
1922	367	1934	47
1923	243	1935	46
1924	0	1937	0
1925–26	62	1938	0
1927	60	1939	17
1928	0	1940	72
1929	42		
1930	28		

President Crampton restated the present situation as regards the Society publishing the proposed monograph and reported that the Executive Committee had decided on the need for further confirmation by the membership before final action. He called for a vote as to whether or not the Society should publish the proposed monograph, realizing that reserve funds of the Society must be used for this purpose, and that the Society must be prepared, if necessary, to stand any loss resulting from the publication.

In the discussion which followed, A. L. Musson asked if offset printing had been considered as a means of lowering costs. President

Crampton stated that this had been considered without favor by the Executive Committee except if reprinting became advisable. F. B. Morrison asked for a review on the scope and nature of the material as well as the authors. This information was furnished by C. E. Terrill. F. B. Morrison then suggested that the various sections be prepared by committees rather than individuals. E. W. Crampton stated that the original proposal called for the writing to be done by individuals subject to review by members of the Committee for Investigations.

A. L. Musson made a motion that the publication be undertaken under the conditions as outlined. This motion was seconded by W. A. Craft and upon vote, the motion was declared carried.

D. W. Colvard read the following report for the Pasture and Range Investigations Committee:

"Your committee on pasture and range investigations in cooperation with the pasture committees of the American Dairy Science Association, American Society of Agronomy and the American Society of Range Management has completed the report on pasture and range research techniques. This manuscript was submitted to the editor of the American Society of Agronomy for publication in the *Agronomy Journal*. Plans have been completed for the report to be published in the January issue of that *Journal*.

"Reprints will be made available at nominal cost by the American Society of Agronomy to the various societies, experiment stations, and others who may be interested in additional copies.

"Your committee wishes to recommend that it be discharged, having completed the assignment for which it was appointed."

C. W. Gay reported that a volume entitled "The History of Livestock in the United States" had been completed. He stressed the need of recording current changes in the livestock field while data are readily available and especially the recording of current history on the development of new breeds. With his report he presented to the Society the bound volume he had written as well as an unbound addenda of more recent material. He suggested that this material remain in the hands of the secretary temporarily, with ultimate disposition to be decided by the Executive Committee.

The following report by the Committee on Information was read by H. H. Biggar:

"The report of this committee must of necessity be practically all devoted to the results of the committee's work covering the last meeting, since this year's work is just getting under way. As usual, news releases covering phases of this meeting are now being made available to publications of the livestock and meat industry. In addition, some news features are being released to Chicago radio stations, Chicago papers and the press wire services including Associated Press, United Press and International News Service.

"Regarding the use of news material last year, I will say that 28 publications dealing with livestock and agriculture have come to our attention which published 64 stories relative to last year's meeting. These papers are located in 15 different states. The articles printed totaled about 25 newspaper columns.

"These publications were as follows:

Beef Cattle Publications—American Aberdeen Angus Journal, American Hereford Journal, Polled Shorthorn Journal, Shorthorn World, and Milking Shorthorn Journal

General Livestock Publications—Breeders Gazette, Breeder Stockman, Arizona Stockman, Denver Record Stockman, Kansas Stockman, Western Livestock Journal, Western Live Stock, and The Cattleman

Farm Papers—Ohio Farmer, Business Farmer, and Kansas City Weekly Star

Hog Publications—American Hampshire Herdsman, Berkshire News, Chester White Journal, and Hog Breeder

Market Papers—Omaha Daily Journal Stockman, Chicago Drovers Journal, Kansas City Drovers Telegram, St. Louis Live Stock Reporter, South St. Paul Livestock Reporter, and Oklahoma Live Stock News

Meat Trade Papers—Butchers Advocate, and National Provisioner

"There have also come to our attention 29 daily papers which used stories emanating from the 1950 Society meeting. These included three Chicago papers—The Chicago Tribune, The Chicago Daily News and The Chicago Herald American.

"In addition stories appeared in ten other Illinois papers, in 3 California papers, 6 New York papers and in papers of Iowa, Pennsylvania, Maryland, Virginia, Ohio, New Jersey and Wyoming.

"The papers cited as using material are only the ones which have come to our attention, but stories were doubtless used in various other agricultural, livestock and daily papers.

"In connection with this year's plans, we wish to thank Dr. Casida for getting to us a copy of the abstracts of papers some weeks ago—thus making it possible to greatly facilitate the work now under way."

E. H. Hostetler, Necrology Committee chairman, presented the names of members who passed away during the year. Memorials are published in this issue of the JOURNAL. Members stood in silent respect.

E. A. Livesay reported that no meetings of the Inter-Society Association Council had been called during the year.

The following report by F. F. McKenzie, representative on the American Association for Advancement of Science Council, was read by Ralph Bogart:

"The AAAS is engaged in a re-examination of its activities which relate primarily to the internal affairs of science in this country. It is clear that the AAAS should not attempt to hold to a pattern of annual meetings that was natural and effective many years ago but which is now outmoded. The technical papers which present detailed results in chemistry, in physics, in mathematics, in zoology, etc., can more properly be presented before meetings sponsored and arranged by the appropriate professional groups. It seems clear that this organization should devote less of its energies to the more detailed and more isolated technical aspects of science and should devote more and more of its energies to broad problems which involve the whole of science, the relations of science to government, and indeed the relations of science to our society as a whole.

"This increased emphasis on broad problems should lead to new activities in wider fields, but it also requires a modification of what the AAAS tries to do within science and for science. In short, there would seem to be a real opportunity to try to "put science back together."

"Your representative has favored and supported the idea that in our modern society it is an absolutely essential matter that science—the results of science—the nature and importance of basic research—the methods of science—the spirit of science—be better understood by government officials, by businessmen, and indeed by all the people.

"It is proposed that the AAAS take up at its next convention the idea of following this policy and getting formal approval from the membership. This, if approved, will call for four main things:

1. A real strengthening of the direct usefulness of the AAAS to scientists and to scientific societies.
2. A shift in emphasis from the more detailed aspects of the various technical branches of science to the broader problems of science as a whole.
3. The cultivation of synthesizing and unifying activities as the main emphasis of the AAAS in its internal work within the body of science.
4. The undertaking of attempts to improve public understanding of science as the main external emphasis of the AAAS.

"It is further recommended that the American Society of Animal Production continue to have a representative on the Council of the American Association for the Advancement of Science."

H. W. Marston, Society representative to the Division of Biology and Agriculture, National Research Council, gave the following report:

"The annual meeting of the Division of Biology and Agriculture was held May 15, 1951, with Dr. Ralph E. Cleland, chairman, presiding.

"The committee on Fulbright Fellowships screened 130 applications during the year. The five subcommittees recommended that 90 of these applications be approved but further screening by the Conference Board reduced the number of approved applications to 32.

"The Agricultural Board is still having difficulties in finding financial support. During the year Dr. W. E. Krauss of Ohio has been succeeded by Dr. R. C. Newton as Chairman of the Board. Several committees of the Board are continuing:

1. *Committee on Public Health Aspects of Brucellosis*
   This committee was especially active in connection with the Third Inter-American Congress on Brucellosis. The proceedings of the Congress are being published as a bulletin of the Pan-American Sanitary Bureau and will be distributed through the National Research Council.
2. *Committee on Animal Health*
   This committee issued a statement on the Hog Cholera Problem in the U. S., published in the April 1951 issue of the Journal of the American Veterinary Association. The committee has also been making an analysis of the laws, rules and regulations governing animal health. A manuscript on the subject is being prepared for publication.
3. *Committee on Animal Nutrition*
   This committee has published reports on recommended nutrient allowances for poultry, swine, dairy cattle, sheep, beef cattle and horses. Additional reports are in preparation for dogs, rabbits and fur-bearing animals. In addition there is available a reprint of an article prepared by H. R. Guilbert and J. K. Loosli on the comparative nutrition of farm animals.

These reports are valuable material for educational and instructional purposes. It is urged that members of the Society not familiar with the report obtain copies. They are available at 50¢ each from the National Research Council.

"The Food and Nutrition Board has continued to develop its activities. Four developments serve to show the diversity of these activities:

1. The study of milk quality in relation to milk regulation.
2. Development of a report, "Therapeutic nutrition, with special reference to military situations."
3. Committee on food protection.
4. Survey of food and nutrition research in the U. S.

"Dr. R. W. Gerard of the American Physiological Society proposed the following resolution which was unanimously adopted:

'Resolved that the representatives of the 26 biological societies meeting as members of the Division of Biology and Agriculture of the National Research Council on May 15, 1951, strongly support legislation, such as that now being considered by several state legislatures, which increases the availability of unclaimed, impounded animals for research by responsible investigators at recognized institutions. Animal experimentation is imperative for future advances in knowledge leading to the alleviation of diseases and suffering of man and beast, as it has proved indispensable in past achievements. These representatives fully concur with the resolution adopted by the National Academy of Sciences at its meeting of April 24, 1951.'

"Dr. D. W. Bronk announced that the National Research Council planned to hold a meeting with representatives from societies affiliated with the Council to consider the matter of closer relationship between societies and the Council. Representatives of Societies on the Council have been growing at such a tremendous rate, it may become necessary to modify the structure of the National Research Council. It has been suggested that affiliation might be made by representatives of fields rather than by representatives of societies. Dr. Bronk made an impressive talk concerning the National Science Foundation."

In a communication to the president, R. W. Phillips stated that the European Animal Husbandry Association was now well established in accordance with the plans given in his report of last year. This organization plans to sponsor an Animal Production Congress to be held in Copenhagen, Denmark, next summer. Dr. Phillips considers informal cooperation desirable but no basis as yet for world association as originally proposed.

The following resolutions were presented by the Resolutions Committee and were passed by the Society:

"Your committee recommends that the Society express its appreciation to the officers, editor, committees and special representatives for effective work during the year. All these have done their work without remuneration and have advanced further the standing of the Society.

"The committee believes that Dr. C. W. Gay is due special mention for his painstaking work in preparing the material on livestock in America.

"The committee recommends the Society thank John Morrell & Company for again providing abstracts of the papers presented at this meeting.

"Although there were many disturbances in connection with the meetings on Friday, the committee recommends that the Society express its appreciation to the Sherman Hotel for again providing rooms and facilities for this annual meeting."

The Report of the Nominating Committee was given as published in the November, 1951 issue of the JOURNAL. In the election that followed, H. M. Briggs was elected President and M. L. Baker was elected Vice-President.

The meeting adjourned at 4 p.m.

MEMORIALS

PAUL GERLAUGH

Paul Gerlaugh was born at Osborn, Clark County, Ohio, April 21, 1891. His father was a prominent breeder and importer of Shorthorn cattle. For a number of years the family also maintained an outstanding herd of Duroc hogs.

Mr. Gerlaugh graduated from Ohio State University in 1913. He then became a member of the animal husbandry staff at Pennsylvania State College. He received a Master's degree from there in 1916. In 1917 he returned to Ohio as agricultural extension agent of Wood, a leading cattle feeding county in the state.

In 1921 Mr. Gerlaugh entered the extension service of Ohio State University as a livestock extension specialist in the department of animal husbandry, under the leadership of Dr. C. W. Gay. During his stay there he did some resident as well as extension teaching and taught the first meats course offered by the animal husbandry department at the university.

Mr. Gerlaugh went to the Ohio Agricultural Experiment station, Wooster, April 15, 1928. From 1928 until the time of his death he was in charge of the beef cattle work there. From 1928 to 1948, inclusive, he served as chairman of what was then the department of animal industry, and from January until July 1, 1951, as acting chairman of the department of animal science.

Paul Gerlaugh was president of the American Society of Animal Production in 1948. He developed the commercial cattle show at the Ohio State Fair and was superintendent of this division of the fair for a number of years. He was well and widely known for his work with beef cattle and was listed in "American Men of Science." His death was caused by leukemia and occurred August 10, 1951.

JOHN ARTHUR HILL

John Arthur Hill died March 10, 1951 at Laramie, Wyoming. He was born near Carrollton, Ohio, June 10, 1880. After receiving his Bachelor of Science degree from the University of Wyoming in 1907, he became wool specialist for the Wyoming Experiment station and in 1910, professor of textile industry. He served in the United States army in 1917–18, achieving the rank of captain. Throughout his life he retained a keen sense of patriotism and interest in military affairs. He became Dean of Agriculture and Director of the Agricultural Experiment station at the University of Wyoming station in 1922, a position which he held until 1950. At the time of his death he was vice president of the university with which he had been associated for nearly 50 years.

Dean Hill was long looked upon as an agricultural leader, not only by his fellow workers in the field of education and research, but by stockmen as well. His advice was sought and respected by leading stockmen. In addition to his personal research in wool and sheep breeding, he developed a program of instruction and research in wool technology at the University of Wyoming, which was outstanding in this field. Many wool specialists of today owe their training in part to him.

Dean Hill's contribution to state and national affairs is attested by his continuous memberhip in the Wyoming State Board of Agriculture from 1923 and the wool advisory committee for the Secretary of Agriculture since 1947. He was active in the American Society of Animal Production which he served as

president. He was honored with an LL.D. by his Alma Mater in 1947 and was the honor guest of the American Society of Animal Production in 1949.

Surviving are his widow, Mrs. Evelyn Hill, and the following children, Robert M., John M., Ross C., Nellis E., and Sally Evelyn (Mrs. John S.) Mackey.

ELMER HOWARD HUGHES

Elmer Howard Hughes was born at Rewey, Wisconsin, April 8, 1887 and died suddenly in his office at the University of California, Davis, California, April 16, 1951.

After receiving the B.S.A. degree at the University of Wisconsin in 1912, he worked for a year as farm manager, going to the department of animal husbandry at the University of Missouri in 1913. There he received a M.A. degree and became assistant to the dean and director of agriculture. After serving with the U. S. army as a second lieutenant during World War I, he went, in 1920, to the University of California and became professor of animal husbandry in 1936. During the period of his service at the University of California, he was granted a Ph.D. in nutrition at the University of Wisconsin.

Professor Hughes had charge of swine investigations at the University of California and was well known for his work in swine nutrition. His contributions on water soluble vitamins were outstanding. He published numerous papers and bulletins on the nutritional requirements of swine. His latest studies concerned the effects of environmental temperature upon the physiological functions of swine.

In 1948, he became chairman of the division of animal husbandry at the University of California, a position which he held at the time of his death.

Professor Hughes married Beulah Baker in 1912. They had no children, but he took a paternal pride and interest in Curtis Rundell Biddick and Russell Richard Biddick, two of his wife's nephews whom they reared and educated. Both were graduates of the University of California; and, both were officers in the U. S. Army Air corps during World War II. Captain Curtis Biddick, the pilot of a B-17, was killed in one of the early missions over Italy and Austria. Professor Hughes mourned this loss as he would have a son.

Professor Hughes is survived by his wife, his father, John Thomas Hughes; a brother, Luther Hughes; a sister, Amelia Hughes, and Russell Richard Biddick.

ERNEST THOMPSON ROBBINS

Ernest Thompson Robbins was born June 27, 1878, on a farm near Payson, Adam county, Illinois. He attended Payson High School, and enrolled at the University of Illinois in 1896 where he received his B.S. degree in 1900. Following graduation he farmed until 1905, when he went to Iowa State College as a member of the animal husbandry staff, receiving a M.S.A. degree in 1907. He left Iowa State College in 1909 to become associate editor of The Breeder's Gazette. He became one of the first farm advisers in Illinois when he was employed in that capacity in Tazewell county from 1913 to 1918. From 1918 until 1920 he managed a large estate and again returned to farm advisory work in DeWitt county in 1920. From June, 1923, until his retirement in September, 1945, Professor Robbins was livestock extension specialist at the University of Illinois. He died January 21, 1951.

Professor Robbins' life was one of accomplishment and leadership. While at the University of Illinois he was a member of the winning collegiate livestock judging team at the International Livestock Show and was valedictorian of his

class. At Iowa State College he was author of three experiment station bulletins. While on the staff of Breeder's Gazette he also taught feeds and feeding, breeds and breeding, and livestock judging at the Chicago Veterinary College. While farm adviser in Tazewell county, he organized the Tazewell County Percheron Breeders Association.

As livestock extension specialist at the University of Illinois, Professor Robbins promoted the McLean county system of swine sanitation which was responsible for tremendous increases in efficiency and income to the swine industry. He also promoted the big team hitch prior to the general adoption of tractor power. He was an authority on all phases of livestock production and management and a noted livestock judge. He was known for his practical advice and ready solution of production problems. He provided a continuous supply of publicity and teaching aids and was author of many publications.

He was a member of Alpha Psi, Alpha Zeta, Gamma Sigma Delta, Epsilon Sigma Phi, and Phi Kappa Phi.

Professor Robbins was an elder of the First Presbyterian Church of Urbana and in addition to serving on the Session for over 25 years had a special interest in the missionary program.

Professor Robbins is survived by his wife, Mrs. Ida F. Robbins; four daughters, Mrs. Helen Garrigus, Mrs. Mary Haworth, Mrs. Dorothy Holzclaw, Mrs. Margaret Ziegler; two sisters, Mrs. John Herring and Edith A. Robbins, and six grandchildren.

DEWITT C. WING

"D.C.W.—no other three initials, cut in granite, will ever mean so much to farm folks who really think things out."

This deep and beautiful memorial was penned upon the passing of DeWitt C. Wing, beloved countryman, lover of animal life, esteemed rural writer, friendly dreamer, and sympathetic philosopher.

The author of those lines had long been a friend, admirer, and associate of D.C.W. From extended, personal observation at close range he knew well that "DeWitt could drive words into picturesque paragraphs as we herd cows into familiar stanchions"—always stimulating and to the reader's benefit. He knew as did farm-minded folk throughout the land that DeWitt Wing had been one of America's ablest exponents of animal agriculture and one of this country's foremost agricultural journalists.

Wing was born in 1878 near Boonville, Missouri, where it was said "a love of the land and all it stands for became an instinctive part of those who were raised there." After a period of study and inspiration at the University of Illinois he turned aside to seek and give expression to those ideals inherent in his early environment. Perhaps of no one could it have been said more truthfully, "You may take the boy out of the country, but you can't take the country out of the boy."

After a brief turn at country journalism, DeWitt joined the famous staff of the Breeder's Gazette, known and enjoyed wherever livestock was bred and fed. Under the tutelage of such masters of writing as Alvin Sanders, Will Goodwin, and Joseph E. Wing (no relation), he grew in style and widened in influence.

For a quarter of a century there came from his pen, through the medium of the Gazette, timely information, helpful counsel, and stimulating encouragement—all phrased in beautiful, readable, and understandable language.

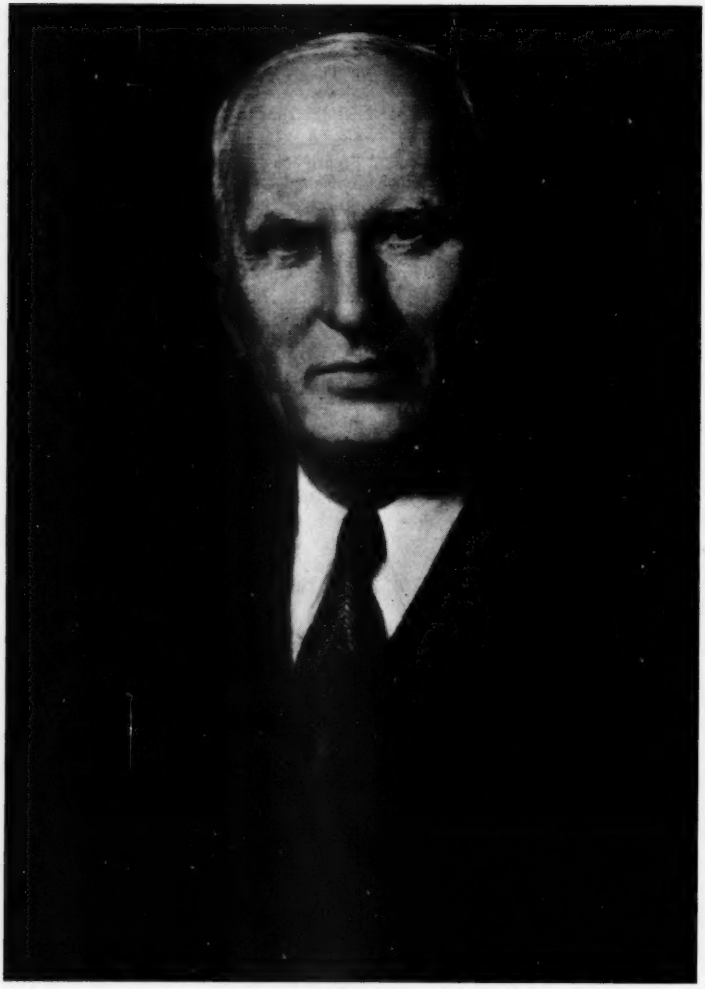
He first left the Middle West to join the Rural New Yorker as its associate editor. Shortly thereafter he bought a small farm in the Catskill mountains of

New York. Here he lived alone and shepherded a flock of sheep. Then in 1934 the Secretary of Agriculture called him into the service of the nation. As a member of the informational staff of the United States Department of Agriculture he worked earnestly until 1945.

That year he went with the Federal Security Agency to help launch the F.F.A. Foundation. Not fully enjoying this assignment he shortly returned to the Middle West, and worked a while for the Agricultural Leaders' Digest, the Aberdeen Angus and the Shorthorn Breeders' Associations.

One of his latest writings was a biography of the late Frank W. Harding, one of America's Shorthorn breeders' great.

Then on March 30 of this year the great heart of DeWitt Wing was stilled and his "mule shed" was locked forever. In line with his expressed wish, his ashes were scattered over the farm where he had tended his sheep—there in the Catskill region in company with Thoreau, John Burroughs, and Rip Van Winkle, immortals of the American rural tradition.



GUSTAV BOHSTEDT

Reproduction of a portrait to the Saddle and Sirloin Club in Chicago by the American Society of Animal Production on November 25, 1951. Gustav Bohstedt was the Honor Guest of the Society during its annual meeting which was being held at that time.

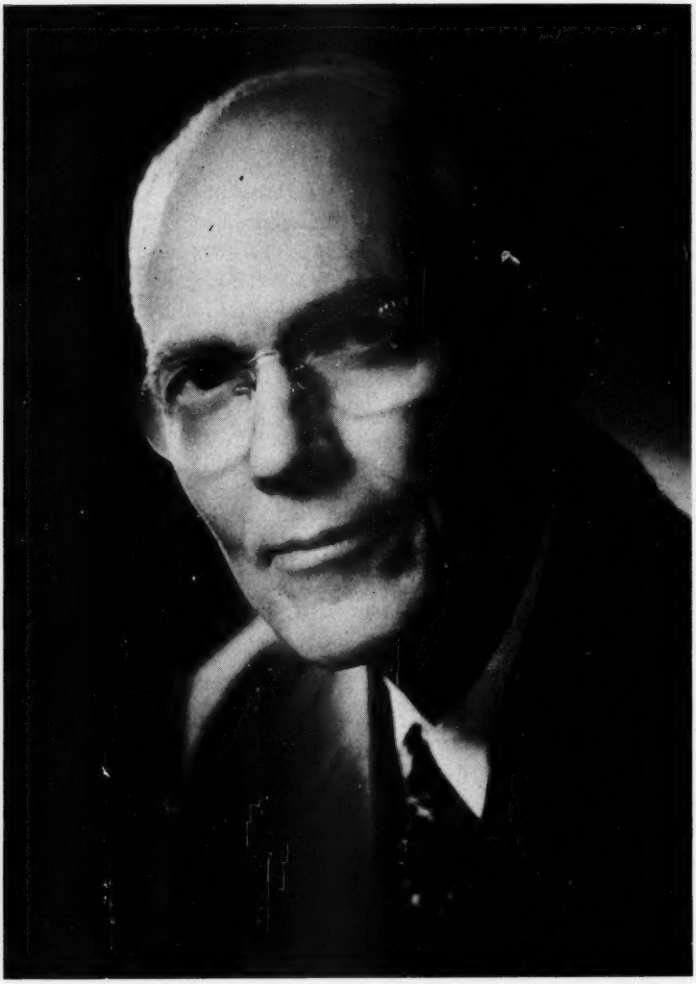
GUSTAV BOHSTEDT

Honor Guest—1951

Gustav Bohstedt was born in Gnissau, Holstein, Germany, June 22, 1887. He became a nationalized citizen of the U. S. A. in 1912. He received his formal training at the University of Wisconsin; the B.S. degree in 1915, the M.S. degree in 1916 and the Ph.D. degree in 1925. As a student he was an assistant in animal husbandry at the University of Wisconsin in 1915–16 and at Iowa State College in 1916–17. In 1917 he returned to Wisconsin where he served as instructor and assistant professor in animal husbandry until 1921. For seven years (1921–1928) he was chief of the department of animal industry in the Ohio Experiment Station. In 1928 he was recalled to Wisconsin as professor of animal and dairy husbandry, and since 1943 he has carried the responsibilities of the chairmanship of the department of animal husbandry at the University of Wisconsin.

Dr. Bohstedt has done extensive research on the mineral and vitamin requirements of farm animals, the value of protein supplements and urea in livestock rations and the influence of various methods of production and storage on the utilization and feeding value of many important forage crops. In recognition of his research contributions he received the Morrison Award in 1950.

Dr. Bohstedt has demonstrated marvelous ability as a teacher and leader of both undergraduate and graduate students. He personifies in an outstanding way the qualities, both scientific and personal, which are desirable in a college teacher. Not only is he capable of interpreting new facts, but equally successful in applying these principles to practical animal production. His influence is strongly felt in the whole field of research, teaching and extension in animal husbandry. Because of his sound judgment and his willingness in making wise suggestions he merits and receives the friendship, confidence and highest respect from all with whom he comes in contact.



ALBERT GARLAND HOGAN

Albert Garland Hogan received the sixth Morrison Award, which was presented to him during the 43rd Annual Meeting of the American Society of Animal Production in Chicago on November 24, 1951.

THE MORRISON AWARD

1951

Albert Garland Hogan is a native Missourian, and a graduate of the University of Missouri, having earned the B.A. and B.S. degrees in agriculture and the M.A. from that institution. He continued graduate work at Yale University, where he received the Doctor of Philosophy degree in Physiological Chemistry. During World War I, he served as a Nutrition Officer, Sanitary Corps, United States Army, with the rank of Captain.

In 1920, he returned to the University of Missouri as professor of animal nutrition, and in 1923, he was appointed chairman of the department of agricultural chemistry. In this dual capacity, he has conducted the research program of the Agricultural Experiment Station in animal nutrition and the undergraduate and graduate teaching programs in that subject.

Dr. Hogan's research activities have dealt primarily with the basic principles of nutrition. He has given more attention to the nutritional requirements of swine and poultry than to other farm animals. He has contributed materially to the knowledge of the nutritional requirements of the pregnant and lactating brood sow and the growing pig. His work with poultry has dealt principally with the vitamin requirements of poultry. The now widely used experimental method of using diets composed of purified nutrients to determine the nutritional requirements of swine and poultry was developed principally in his laboratory.

The characteristically thorough and reliable manner in which his research has been planned and conducted has produced results that are of immeasurable value to the livestock industry. The basic information which his research has produced has been used extensively in applied animal feeding research.

LORIN E. HARRIS

Lorin E. Harris was awarded the fourth American Feed Manufacturers' Award, which was presented to him during the 43rd annual meeting of the American Society of Animal Production in Chicago on November 24, 1951.

AMERICAN FEED MANUFACTURERS ASSOCIATION AWARD

1951

Dr. Lorin E. Harris was born in Kimberly Idaho, May 31, 1915. He received his B.S. degree from Utah State Agricultural College in 1937. His M.S. degree was completed in 1938 and his Ph.D. degree in 1940, both from the University of Illinois.

He has held the following positions: junior animal husbandman, University of Hawaii, 1940–41; instructor in animal husbandry, University of Arkansas, 1942; U.S.D.A. agent, 1942–43; research associate, school of nutrition, Cornell University, 1943–45; associate professor of animal husbandry, Utah State Agricultural College, 1945–50; professor and chairman of the Utah State Agricultural College Institute of Nutrition, 1950-date.

Dr. Harris' contributions to knowledge of the nutrition of animals have been especially important in the areas involving the utilization of urea by cattle and sheep, the effects of feeding DDT-treated forages to farm and laboratory animals, the utilization of the herbage of the western ranges by sheep, and quantitatively defining the nutritional requirements of fur bearing animals. Particularly important are the techniques which he has devised for conducting nutritional studies with range sheep, and for studying the adequacy of the native herbage and in determining the supplements required to permit profitable livestock production on these ranges. The careful manner in which his experiments were planned and the thorough statistical treatment of the data, as best exemplified in his studies of the protein, calcium, phosphorus, vitamin D and thiamine requirements of foxes and minks, make these reports models for nutrition experiments to be followed with other species of animals. Of particular note, too, is the fact that his scientific reports are all supported by data obtained from adequate numbers of animals to fully substantiate the conclusions drawn. The results of his research are finding use in practical livestock production.

To his credit also, is Dr. Harris' ability to stimulate co-operative research in nutrition, and thus, through the combined efforts of several groups it has been possible with limited facilities to complete research that would otherwise have been impossible.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN, AND SPECIAL ASSIGNMENTS FOR 1952

Standing Committees

Committee on Investigation.....C. E. Terrill
Committee on Instruction.....A. L. Anderson
Committee on Extension.....H. G. Zavoral
Committee on Membership.....M. L. Baker

Special Committees

Committee on Information.....R. C. Pollock
Committee on Necrology.....E. F. Ferrin
Committee on Nominations.....A. D. Weber
Committee on Morrison Award.....M. L. Baker
Committee on American Feed Manufacturers' Award.....T. S. Hamilton
Committee on Registration and Facilities.....J. I. Miller

Program Committees

Breeding and Genetics.....W. J. Tyler
Extension.....H. G. Zavoral
Meats.....R. W. Bray
Nutrition.....W. D. Gallup
Pastures and Forages.....C. S. Hobbs
Physiology.....Joseph Meites

Special Representatives

Inter-Society Association Council.....E. A. Livesay
Historian.....C. W. Gay
American Association for Advancement of Science Council.....H. H. Cole
Division of Biology and Agriculture, NRC.....H. W. Marston
European Animal Husbandry Association.....R. W. Phillips
Ralston Purina Award Committee.....R. H. Nelson

NEWS AND NOTES

Applications for the Ralston-Purina research fellowship should be on file by March 1. Application blanks may be obtained from the Ralston-Purina Research Awards Committee in care of Mr. J. D. Sykes, Ralston-Purina Co., St. Louis, Missouri. The fellowships are for $1440 annually and awards will be made in the fields of nutrition and physiology research as applied to dairy, poultry, and animal husbandry, and in research in transmissible diseases of livestock and poultry. Individuals qualified for graduate study in any Land-Grant Agriculture College and approved Veterinary Colleges are eligible.

The Second International Congress of Physiology and Pathology of Animal Reproduction and of Artificial Insemination will be held at the Royal Veterinary and Agricultural College in Copenhagen on July 7–11, 1952. The last day for acceptance of papers for the sectional meetings is April 1, 1952. Communications should be addressed to Professor Ed. Sorensen, Secretary General, The Royal Veterinary and Agricultural College, Bülowsvej 13, Copenhagen V, Denmark.

The VI International Congress of Animal Husbandry is to be held in Copenhagen, Denmark, July 9–14, 1952. Lectures and discussions are planned on breeding methods, physiology in relation to the vitamin B complex, animal nutrition and fertility, methods of calculating costs of animal production, and advisory service in animal husbandry. The Secretary of the Congress is Holber Aersoe, The Ministry of Agriculture, Copenhagen.

A five-week conference on Biostatistics is to be held at Iowa State College at Ames, June 16 to July 23, 1952. It will be conducted as was the highly successful conference on *Heterosis* in 1950. The general theme is the use of quantitative methods in biology. Each day will begin with a lecture by a biologist on a problem which seems amenable to quantitative treatment, and a lecture by a statistician on quantitative methods which seem appropriate for problems of that kind. Discussion sessions will be held later in the day. General themes for the five weeks are tentatively set as: Development of quantitative biology; Specification of populations and their processes; Estimation of populations; Individual growth; Biomathematical mechanisms within the individual and species. For details inquire of T. A. Bancroft, Statistics Department, Ames, Iowa.

Don Kinsman, holding degrees from the Universities of Massachusetts and New Hampshire, has joined the animal and dairy husbandry staff of the University of Vermont and State Agricultural Experiment Station. He will supervise livestock research at the Morgan Horse Farm, Middlebury, recently acquired from the federal government.

Phase Microscopy by Bennett, Jupnik, Osterberg and Richards was published by John Wiley and Sons, Inc., New York in Sept., 1951. This book deals with the theory of phase microscopy and the instruments used. Discussions are presented on technics and on uses in biology, medicine and industry.

M. R. McClung, who has been on leave of absence from the University of Arkansas for the past two years, has completed residence work towards a Ph.D. degree in breeding at Iowa State College, and has returned to the former institution where he is doing both teaching and research.

A Study of Antimetabolites by D. W. Woolley was published by John Wiley & Sons, Inc., New York in January, 1952. It covers investigations of substances which specifically produce deficiency diseases in living organisms and presents a view of the mechanism of action of these substances.

Vertebrate Sexual Cycles by W. S. Bullough was published by Metheun & Co., Ltd., London, in December, 1951. The author has intended to present a brief but up-to-date account of our knowledge and of the current theories of the sexual physiology of the vertebrates.

J. J. Wanderstock has joined the Staff of the School of Hotel Administration at Statler Hall, Cornell University. His primary responsibility will be teaching a course in meats, poultry and fish.

The Classification of West African Livestock by I. L. Mason was published by the Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England, in November, 1951. It is a comprehensive classification of the livestock of this region and provides a framework of classification into which all local breeds and types of livestock can be fitted.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should contain a clear statement of the purpose of the investigation and its relation to other work in the same field, but long reviews should be avoided. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results, or their relation to some problem of the livestock industry. Each paper should end with a brief summary outlining the points proved in the investigation and their application, or their relation to a livestock problem.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. The author or his institution except in the case of invited review papers, will be required to purchase at least 100 reprints of his paper. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints that will be ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts". *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest concerning the members, and other items of interest to the membership. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. L. E. Casida, Department of Genetics, University of Wisconsin, Madison, Wisconsin, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.